ENERGY USE ENGINEERING DEPARTMENT

PROJECT 7859

Residential Natural Gas Space Heating Potential Impact on Energy Conservation and Energy Needs in B. C. 1980-2005

ENERGY CONSERVATION DIVISION

B.C. HYDRO AND POWER AUTHORITY

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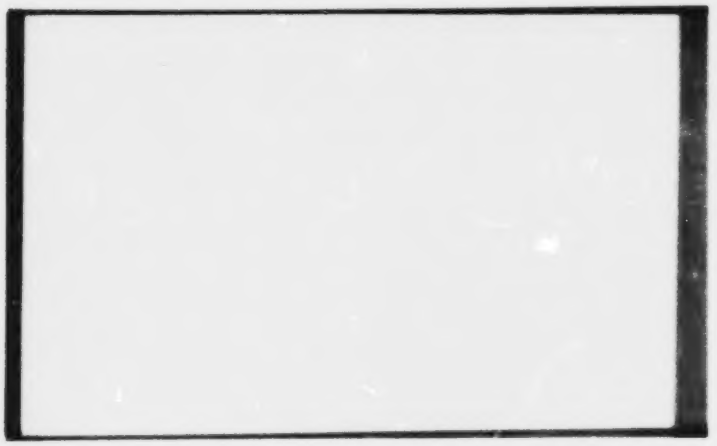

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PROJECT 7859

Residential Natural Gas Space Heating Potential Impact on Energy Conservation and Energy Needs in B. C. 1980-2005

SYNOPSIS:

Based on probable impact, by the year 2005 the average gas heated home in the Lower Mainland will use approximately 428 therms (451 BU) or 50% less gas for space heating than in 1980.

PROJECT:

Initiated/Requested by:	R. W. Racine, P.Eng.
Date Completed:	20 July 1982
Completed by:	G. H. Pinch, P.Eng./ Z. El-Ramly, P.Eng.
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ENERGY USE ENGINEERING DEPARTMENT

PROJECT SUMMARY

PROJECT NO. 7859 PRIORITY 3

TITLE: RESIDENTIAL GAS SPACE HEATING - POTENTIAL IMPACT ON ENERGY CONSERVATION & ENERGY NEEDS IN B.C. - 1980-2005

INITIATED/REQUESTED BY: T. J. Newton

ASSIGNED TO: R. T. Martin/R. G. Cawker ASSIGNED BY: R. W. Racine

DATE ASSIGNED: 1 February 1978 DATE REQUIRED: by 1 June 1978

ESTIMATED COMPLETION: May 1978 COMPLETED: 20 July 1982

OBJECTIVES AND NOTES:

Planning and implementing activities for meeting and alleviating conventional electric, gas and oil energy needs requires utilization and impact data on:

a) Current practical solutions,
b) Potential alternative solutions,

for the B.C. situations involved.

Energy conservation (all applications) can be an element contributing to the desired solutions. Provide an updated report covering:

1. a) and b) above in general.
2. Per unit characteristics summary for the situation involved, e.g. a 1200 sq. ft. house, insulated as recommended (refer 'C' in H 308 and 309).
3. Example applications and impacts on Vancouver Island for the 1980-2005 25 year period.

Coordinate with others involved. Provide a pessimistic, probable and optimistic range of possibilities where appropriate. Refer DG 223 and 506.

The primary objective is to develop an updated summary based on available information by 1 June 1978 with the idea that the report can be updated and simplified later if required.

COPIES TO: DEPARTMENT MANAGER (THEN RECORD FILE), BLUE FILE, SUPERVISOR, (R. G. Cawker)
T. J. Newton G.D.A. Henriques
R. Schneider Z. El-Ramly

PLEASE ADVISE AS SOON AS POSSIBLE IF CHANGES ARE REQUIRED ABOVE

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Appendix V - Flow Chart of Weatherization Computer Program

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SUMMARY

This project deals with residential sector energy conservation as a result of weatherization, reduced infiltration and use of more efficient equipment and its impact on natural gas requirements in the Lower Mainland area of B. C. up to the year 2005.

The general approach used in this and other impact studies is summarized in Appendix I.

As the factors involved in residential conservation vary widely in first cost, effectiveness and ease of accomplishment and are greatly influenced by climate, the approach was expanded to consider conservation on a regional basis by style of dwelling and by heat loss components.

B. C. Hydro load growth forecasts to 2005, together with CMHC data on the average residence and our experience with insulation levels, were used to produce an analysis of potential energy savings.

Table 1 provides a summary of the findings for the possibilities considered.

Figure 1 is a graphical representation of Table 1. Figure 2 is a presentation of the probable energy savings due to each heat losing element or mechanism considered in this report.

Base year 1980: average gas space heating consumption per account = 849 therms/year.

Forecast Year	1985			1995			2005		
Forecast	Pes	Prob	Opt	Pes	Prob	Opt	Pes	Prob	Opt
Per Residential Space Heating Account Therms*/yr (Billing Units/yr)	43 (45)	73 (77)	126 (133)	192 (202)	274 (289)	359 (379)	337 (355)	428 (451)	518 (546)
% **	5	9	15	23	32	42	40	50	61

* This represents the reduction in average annual consumption per account based on the B. C. Hydro growth forecast to the year 2005 and related to the 1980 base year.

** This represents the reduction as a percentage of 1980 natural gas space heating usage.

Table 1: Annual Reduction in Natural Gas Space Heating Consumption: 1980-2005

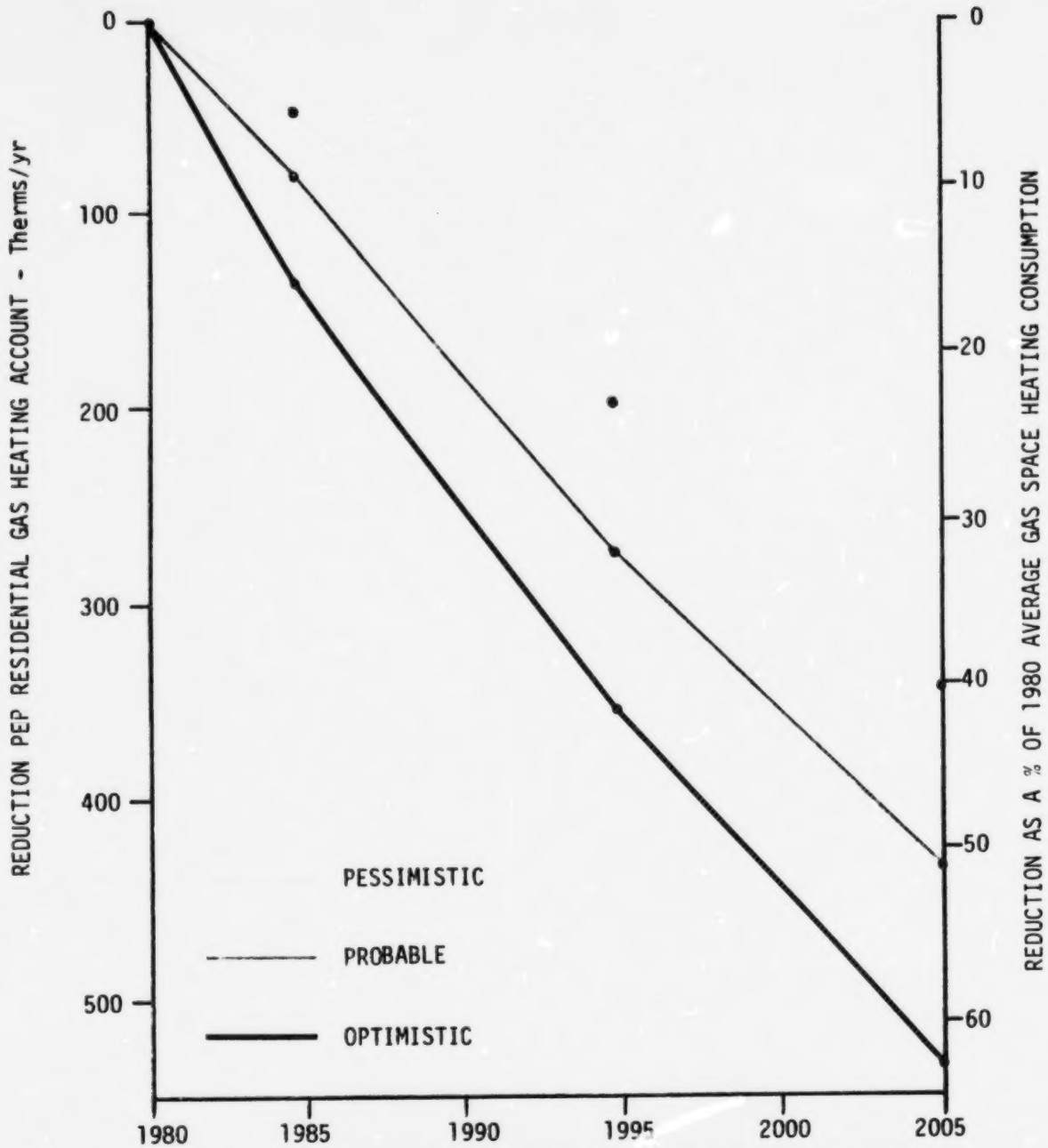


FIGURE 1: ANNUAL REDUCTIONS IN GAS HEATING CONSUMPTION PER RESIDENTIAL HEATING ACCOUNT: 1980-2005 Therms/yr

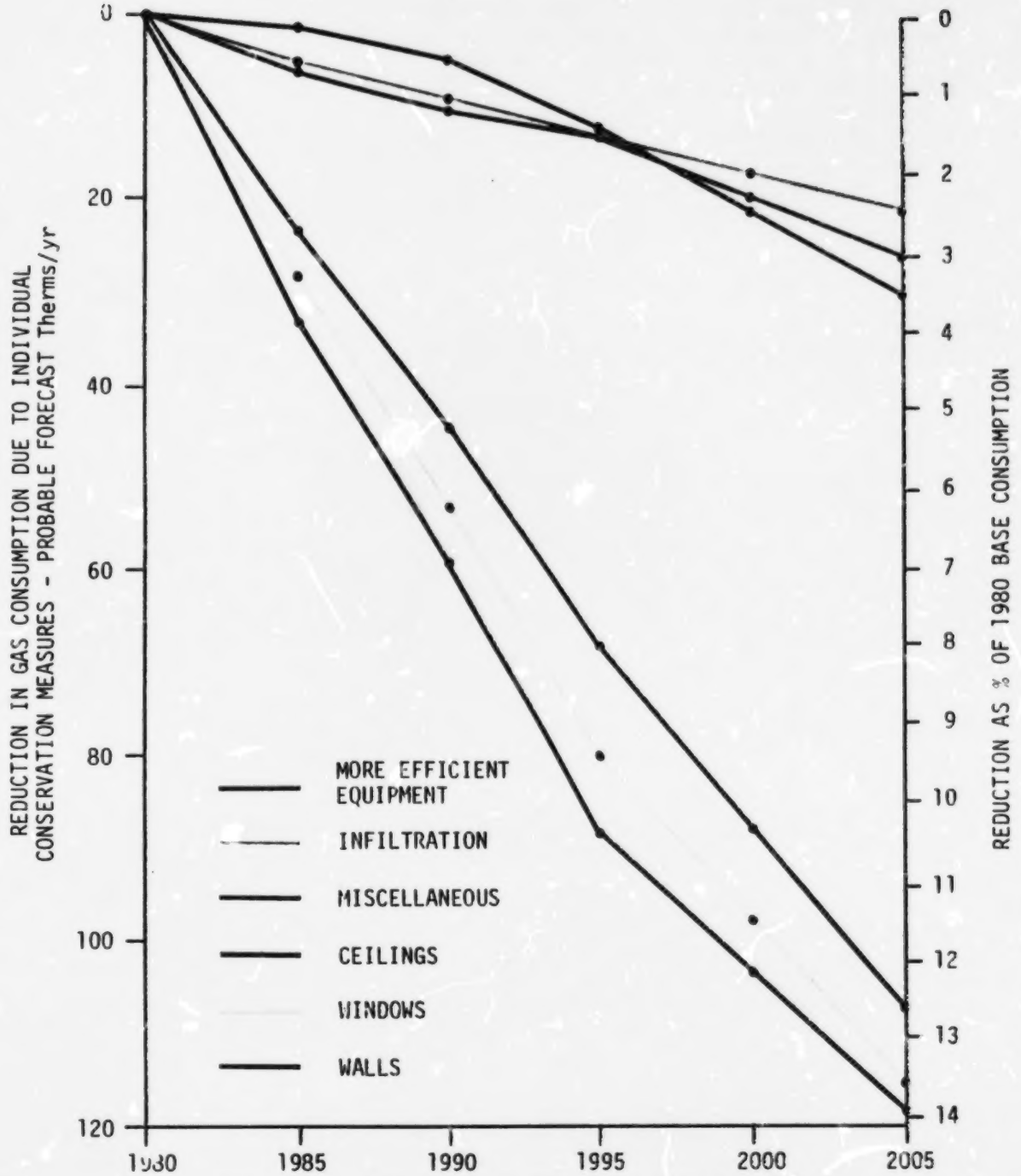


FIGURE 2: IMPACT OF VARIOUS CONSERVATION MEASURES - RESIDENTIAL GAS HEATING 1980-2005

1. INTRODUCTION

In 1980, B. C. Hydro had over 240,000 residential gas heating accounts in the Lower Mainland area of B. C. and these accounts consumed 3.09 x 10^8 Billing Units (2.93 x 10^8 therms)[1] of natural gas. Of this, it is estimated that approximately 2.14 x 10^8 Billing Units (2.03 x 10^8 therms)[2] was used for home heating with the balance used for domestic hot water, cooking or other uses. Thus, residential space heating accounts for approximately 25% of all the gas sold by B. C. Hydro (see Figure 1). Normalized to a standard heating season, the average residential account was estimated to consume 849 therms/year* for space heating.

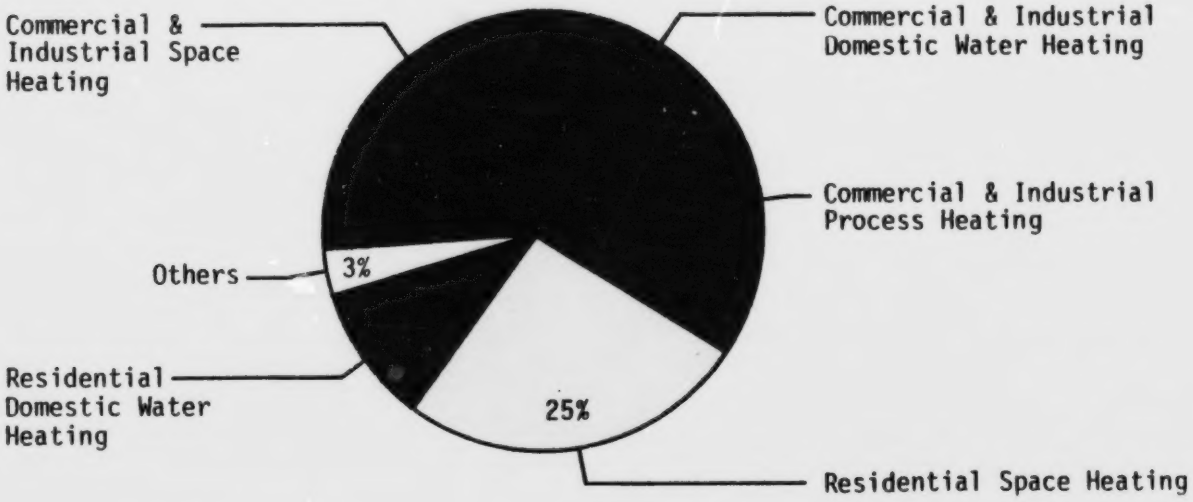


Figure 1: Ratios of 1979/80 Natural Gas Consumption in the Lower Mainland

* Results of a recent survey indicate that this estimate may be low and that space heating consumption may be in the range of 925-1,015 therms/year. As some of the savings in this report have been determined as a percentage of the heating consumption, results would be affected accordingly.

[1] Projections of Gross Load Requirements 1980/81: 1990/91. Corporate Planning Department, B. C. Hydro

[2] Breakdown of 1979/80 natural gas consumption provided by B. C. Hydro Gas Supply Department.

With residential heating representing such a large proportion of total consumption, permanent measures taken to reduce home heating consumption could have a significant effect or gas sales and load growth in the future. This report tries to isolate the various heat loss mechanisms in gas heated residences and estimates the pessimistic, probable and optimistic impact of various energy conservation measures on residential natural gas heating consumption for the period 1980-2005.

This analysis examines the effect of:

- higher levels of insulation;
- higher levels of glazing;
- reduction of infiltration;
- use of air-to-air heat exchangers;
- use of more efficient furnaces.

While considering the following factors:

- existing and future housing (i.e. number of accounts);
- housing standards;
- the degree of improvement likely to occur to these standards;
- climate;
- demolitions;
- conversions.

B. C. Hydro distributes natural gas only in the Lower Mainland area of British Columbia, and the Lower Mainland has been subdivided into two regions, Metro and Fraser Valley. The Victoria gas distribution system uses a butane-air mixture and is not included in this study.

This study takes into account only those features which can be implemented on a technical fix basis - i.e. no major changes in lifestyle or radical architectural changes are included and no shortages or restrictions are assumed to limit the usage of electricity, gas or oil. It is thus assumed that within the period of study, buildings will outwardly appear much the same as those existing today, with interior conditions of temperature and humidity being maintained at comfortable levels.

A similar study was undertaken for electric heating[1] and methods and assumptions established for that study have been employed for this report.

1 Project 7857: Residential Electric Space Heating - Potential Impact on Energy Conservation and Energy Needs in B. C. 1980-2005

2. FACTORS AFFECTING SPACE HEATING NEEDS

For a certain housing unit, the annual space heating requirement is a function of:

- house size and the area of the individual elements of the building envelope;
- resistance of the building envelope to heat flow;
- heating system efficiency;
- heating system control;
- severity of the heating season in the area.

The total space heating needs in B. C. Hydro's gas service area at any point in time, is the summation over the housing stock at that time, of all the requirements for the individual units.

The average space heating consumption per unit or account is the total requirements divided by the number of accounts. This chapter examines the factors that could result in a change in the average consumption and are not directly related to energy conservation. Chapter 4 will examine energy conservation opportunities.

2.1 Current Housing Stock

Insulation levels in existing housing are highly dependent on the period of construction, with older housing, built when energy was cheap, having less insulation than recent construction (see Table 1).

Year of Construction	pre 1960	1960-70	1970-75	1975-78	1978-80
Insulation values existing in:	R U	R U	R U	R U	R U
ceilings	7 .116	7 .116	10 .089	12 .078	20 .053
walls	0 .252	7 .109	7 .109	10 .096	12 .088
windows	S 1.1	S 1.1	S 1.1	S 1.1	D .59

Insulating (R) values are given in Imperial units (hr.ft².°F/Btu)
S = single glazing
D = double glazing

Table 1: Existing Insulation Levels - Gas Heating Accounts

There are differences in current housing stock between Metropolitan Vancouver (Metro) and Fraser Valley regions due to the fact that Metro has a predominance of older homes, whereas the growth in the Fraser Valley has been more recent and has been built to higher average standards. Therefore,

housing stocks in each region have been broken down into year of construction to determine average existing insulation levels. Complete tables on the number of existing accounts are contained in Appendix II.

2.2 Future Housing Stock

Insulation and glazing levels, and the number and style of dwelling will affect future average consumptions.

Future insulation levels are expected to be higher than current levels and are covered in detail in Chapters 4 and 7.

Future accounts are expected to remain overwhelmingly single family dwellings (as exhibited by existing stock) with relatively few row houses or other accounts. (Apartments using natural gas for space heating are predominantly bulk metered and are classified as commercial rather than residential accounts. They are treated in Report #7858, Commercial Industrial Natural Gas Space Heating's Potential Impact on Energy Conservation and Energy Needs in B. C. 1980-2005.)

See Chapter 3 and Appendix II for further details on the number of future accounts.

2.3 Demolition of Old Buildings

Demolition of old, poorly insulated housing and replacement with energy efficient housing would be one way of reducing average energy consumption without actually increasing the number of accounts. If old, poorly insulated housing is replaced with another type of structure (i.e. commercial or industrial buildings) it is removed as a residential account and thus improves the average consumption of remaining housing. The identical phenomenon would be observed with major retrofitting.

Demolition is treated as an equivalent retrofit to future levels, i.e. penetration rates are increased to allow for demolition.

2.4 Conversion to Gas Heating From Other Fuels

It is expected that under the impetus of higher oil prices and the Canadian Oil Substitution Program (COSP) a great many oil heated homes will convert to natural gas. Thus a large number of new accounts will be added to our records but they will be old houses and not necessarily up to the insulation standards of new housing. Such housing will have a negative effect (i.e. increase in average consumption) as they are usually older homes with insulation levels below the 1980 average.

Forecasts of conversions are made by B. C. Hydro Gas Division and these have been accounted for in this study (see Table 2). For purposes of this analysis, we have assumed that all conversions are pre-1960 housing.

Region/Period	1980-85	1985-90	1990-2005
Metro	28,163	7,500	0
Fraser Valley	8,587	10,000	0

Table 2: Forecast of Residential Conversions to Natural Gas Heating (Source: B. C. Hydro Gas Division)

2.5 Climate

Annual heating needs are proportional to the extent and severity of the heating season as measured in degree days; the longer and colder the heating season, the more fuel is used.

Both regions, Metro and Fraser Valley, are considered to be subject to the same climatic influences.

3. SOURCES OF DATA

Data are available for both regions (Metro and Fraser Valley) as to the number of residential gas heating accounts, style of dwellings and average consumption per residential heating account, thus making it possible to analyze potential energy savings on a regional basis.

Statistics Canada, Canada Mortgage and Housing (CMHC) and B. C. Hydro also have data on average sizes of single and row housing, plus average window, wall and ceiling areas for each type of dwelling. Also, because of long-standing involvement with residential heating, B. C. Hydro has a knowledge of the insulating and glazing standards used at different times. Therefore, existing housing stocks have been disaggregated into dwelling styles, average heat losing element areas and, through the year of construction, into the existing insulation levels and therefore existing coefficients of heat transmission (U values).

Estimates of the number of residential gas heating accounts for 1985 and 1990 were obtained from the 1980 Projections of Gross Load Requirements prepared by the Corporate Planning Department of B. C. Hydro. Figures for 1995 and 2005 were obtained from the 30 Fiscal Year Forecast of Accounts prepared by B. C. Hydro Gas.

Data on existing gas heating accounts by style of dwelling was obtained from the Administrative and Commercial Services Department of B. C. Hydro. Future gas heating accounts were disaggregated into styles in the same ratio as exhibited by the 1980 stock. An example is contained in Table 3, with a complete tabulation for both regions contained in Appendix II.

METRO REGION

Year	1980		1985	1995	2005
Style	No	%	No	No	No
Total	155051	100	201000	264500	309000
Single	147298	95	190950	251270	293550
Row	4652	3	6030	7940	9270
Other	3101	2	4020	5290	6180

Table 3: Gas Heating Accounts by Style of Dwelling

4. CONSERVATION OPPORTUNITIES

Before practical energy conservation measures can be undertaken, it is necessary to know how the energy is currently being expended.

4.1 Analysis of Existing Heat Losses

In the average gas heated home with a standard heating system, the seasonal overall efficiency of the system is approximately 69%, i.e. 31% of the heat (gas) input to the furnace (or boiler) is lost, mostly up the chimney. 20% is combustion losses - the heat in the hot exhaust gases going up the chimney when the burner is on; the other 11% is due to standby losses that occur when the burner is off.

Heat is lost through the various elements of the building envelope, such as ceilings, walls, windows, floors, slab edges, etc. The equation for heat loss through any element is:

$$Q_E = A \times U \times TD$$

where Q_E = heat loss through an element

A = area of the element

U = coefficient of heat transmission

TD = temperature difference between inside and outside

and this equation can be used to compare the heat losses through the various elements.

An average gas heated home has been derived from data contained in Chapters 2 & 3 and Appendix II, and average areas (A_{av}) and U values (U_{av}) were calculated for the major elements (ceilings, walls, windows) by a computer program as explained in Clause 7.1.1. The product of these average U and A values was used to determine the relative heat loss ratios of each element.

Data on areas and U values for miscellaneous elements, such as floors, basement walls, slab edges, etc., are not as reliable as those for the major elements and it is not possible to determine the heat loss through them as rigorously as for the major elements. Experience indicates that heat losses through these miscellaneous elements is approximately 10% of the total heat (gas) input to the house, and this value has been assumed in this analysis.

It is known that a significant proportion of the heat loss in any home is due to infiltration. The average gas heated Lower Mainland home has an air change rate of one air change per hour. The formula for the energy required to heat infiltra-

tion or ventilation air is Q_I = 1.08 x cfm x TD, which is similar in form to the equation for heat loss through building elements and can therefore be used to relate infiltration losses to the other losses.

In this manner, heat losses for the average gas heated dwelling were apportioned as shown in Table 4 and Figure 2, based on the average heating consumption per account of 849 therms/year:

Heat Loss Mechanism	%	Therms/Yr
Combustion Losses	20	170
Windows	19	161
Walls	16	136
Infiltration	14	119
Standby Losses	11	93
Ceilings	10	85
Miscellaneous Elements	10	85
Total	100	849

Table 4: Heat Losses in Average Lower Mainland Gas Heated Dwelling - 1980

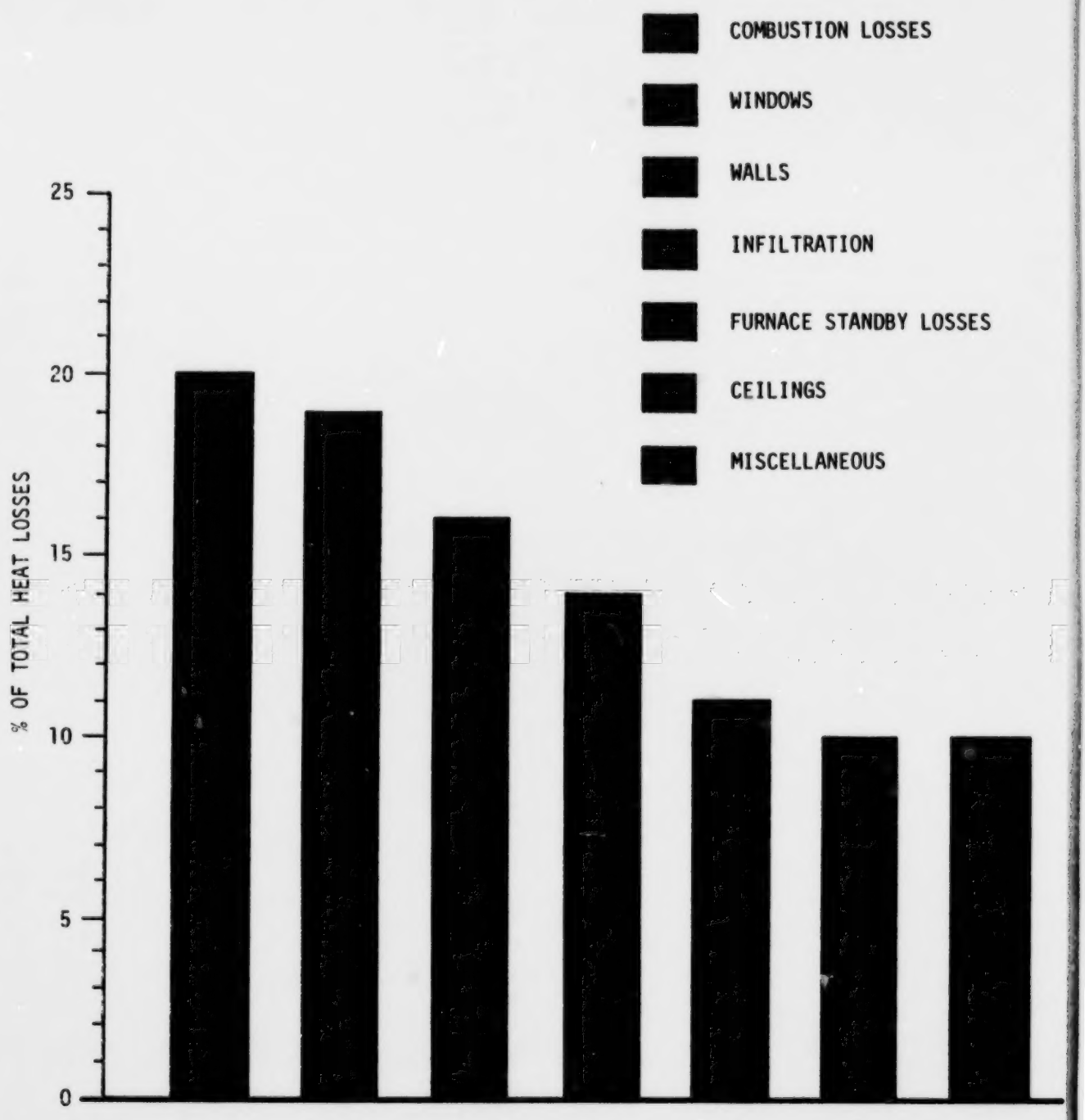


FIGURE 2: RELATIVE HEAT LOSSES - AVERAGE GAS HEATED DWELLING, 1980

These are not total heat losses, as a portion of annual solar and internal gains is also lost through the above mechanisms in the same ratios. Thus, the above losses are what could be termed metered heat losses, rather than total heat losses, and it is metered losses we are interested in reducing.

4.2 Potential For Conservation

Those elements with the greatest losses offer the greatest opportunities for savings, but the cost and ease of achieving these savings must also be considered. It is usually easier and less costly to incorporate efficiency into new buildings than it is to retrofit existing structures, therefore new housing is expected to be much more energy efficient than old housing.

A number of simple methods of reducing heat losses are available that can be utilized in any type of home without sacrificing lifestyle, involve minimal or no architectural changes and are relatively inexpensive. These include the following.

4.2.1 Building Envelope

This is the area of greatest potential energy savings for space heating.

Buildings can be designed to be much more energy efficient than present designs and many innovative building techniques are being tried across North America to build energy efficient housing at a reasonable cost. Many older homes were built with single glazed windows and no insulation whatsoever; thus they are prime candidates for retrofitting.

The various means of improving the energy efficiency of housing are:

4.2.1.1 Wall and Ceiling Insulation

Insulation is the best known and most widely used device employed to reduce heat loss from buildings. The addition of insulation to existing housing and the use of more insulation in new housing than is the current practice, are obvious ways of reducing future space heating needs.

Walls and ceilings generally are the largest areas exposed to the weather, are easy elements to insulate and offer the most cost effective opportunities to insulation improvements. If

insulated to optimum levels (see clause 4.2.1.3) ceiling heat losses could be reduced by approximately 65% and wall losses by approximately 57%.

4.2.1.2 Glazing

In the average single family dwelling, windows constitute a small percentage of the area exposed to the weather but because of generally poor thermal properties, glass and glazing constitute a significant proportion of the heat loss from a building and therefore constitute a great opportunity for energy conservation. If all glazing were upgraded to optimum levels, window heat losses could be reduced by 45%.

4.2.1.3 Optimum Levels of Insulation and Glazing

There are several standards or recommended insulation levels for homes in Canada, each somewhat different from the other. Residential Standards, issued by the Associate Committee on the National Building Code, the Measures for Energy Conservation in New Buildings (also by the Associate Committee on the National Building Code), the Double E Energy Efficient Home Program sponsored by the Canadian Electrical Association, CMHC (Canada Mortgage and Housing) and B. C. Hydro all offer different opinions on the "correct" levels of insulation and glazing, although they serve different purposes; i.e. the Residential Standards and the "Measures" are meant for regulatory purposes, while the CEA Double E and B. C. Hydro recommendations are intended for good overall economy and energy conservation.

A 1978 project report (#7839, Optimum Levels of Insulation) resulted in the issuance of Data Sheets H 205 and H 206 (see Appendix III) delineating the economic optimum levels of insulation and glazing for British Columbia homes. The economic optimum level of insulation is that which would result in energy cost savings, over the life of the investment, of more than the initial cost of installing it. Optimum levels of insulation for major elements were taken from Data Sheet H 206 and are summarized in Table 5.

Element	Optimum	U Value
Ceiling	R 28*	0.036
Walls	R 20	0.060
Windows	DG	0.59

Table 5: Optimum Levels of Insulation - Gas Heating - Lower Mainland

4.2.1.4 Miscellaneous Elements

Improvements to miscellaneous elements consist primarily of insulating floors over exposed areas, crawl spaces, basements or slab edges. In most cases the areas to be insulated are relatively small, consequently, the savings to be realized are small. Also, insulating these elements is "low profile" work, often not considered to be of primary importance.

It is estimated that miscellaneous losses could be reduced by 60%, or 51 therms/year/account, although relatively high costs for such small savings will tend to deter achieving maximum savings.

4.2.2 Infiltration

There are currently no measurable standards for infiltration into a house. It occurs through structural imperfections in the building or building components and is increased through the use of exhaust fans and clothes dryers, and a requirement for combustion air for the furnace.

Experience indicates that there is one air change per hour (AC/hr) in the average gas heated home built prior to 1980, and it is the heating of this air that accounts for the 119 therms/yr.

* Natural gas prices have risen more rapidly than predicted in 1978; consequently, R28 is no longer the economic optimum level of insulation. In October 1981, H 206 was revised, increasing recommended ceiling insulation to R40 to reflect increasing gas prices and to agree with the CEA Double E recommendations. The impact of this change is expected to be small and this study has not been revised to reflect this change, although this could be done at a later date.

While an infiltration rate as low as 0.2 air changes would provide adequate combustion air for a gas furnace and water heater in an average or typical home, the operation of exhaust fans, clothes dryers or a fire in the fireplace could result in air starvation of the furnace with dangerous results, unless provisions were made to ensure adequate air supply for all purposes.

An infiltration rate of 0.5 AC/hr will satisfy normal combustion and exhaust air requirements; therefore, a 50% reduction in heat loss due to infiltration is considered to be optimal, and the actual reduction will be a percentage of this.

Infiltration can be reduced with better weatherstripping, caulking, sealing and air vapour barriers. Most of these measures are relatively inexpensive and can be done by the homeowner, thus, market penetration of these measures should be rapid and extensive. However, the benefits are not as obvious and do not carry as high a profile as other conservation measures, thus detracting from rapid implementation.

Further reductions in infiltration heat loss could be achieved by the use of air-to-air heat exchangers to recover some of the heat lost with the air discharged by exhaust fans and clothes dryers. Units are currently available which can recover approximately 70% of the heat in the exhaust air. Assuming that an infiltration rate of 0.5 AC/hr will be achieved with weatherstripping, etc., and that 0.2 AC/hr is required for combustion air and is lost up the chimney, then only 0.3 AC/hr remains to pass through the heat exchanger. Thus, the potential savings due to air-to-air heat exchangers is 21% of present infiltration heat loss.

4.2.3 More Efficient Equipment and Application

Equipment losses consist of both combustion and standby losses, and equipment is available that will reduce one or both of these losses. The equipment includes:

- vent dampers;
- electronic (spark) ignition;
- condensing furnaces (and boilers);
- outdoor furnaces.

4.2.3.1 Vent Dampers

Chimney losses can be reduced by the installation of a damper in the furnace vent. These open when the burner is on and close when the burner is off. When closed, the damper impedes the flow of air through the furnace and draft diverter and up the chimney.

Units are available which are approved for retrofit to existing furnaces, as well as for new installations.

4.2.3.2 Spark Ignition

The pilot light, which consumes approximately 80 therms per year, is also essentially wasted. While the pilot light does help to keep the heat exchanger warm while the furnace is off, thus reducing the time and energy needed to bring the furnace up to operating temperature during the next "on" cycle, it also creates a thermosiphon effect, drawing air through the furnace, heating it and wasting it up the chimney. Spark ignition is readily available on new furnaces and as a retrofit package for most existing furnaces.

Elimination of standing pilots would therefore save energy, although this would not completely eliminate the flow of heated air up the chimney.

The effects of spark ignition and vent dampers are highly interdependent and since both are required to obtain optimum reduction in standby losses, their effects have been combined. It is estimated that this combination could reduce average consumption by 70 therms/year.

4.2.3.3 High Efficiency Furnaces

While spark ignition and vent dampers reduce standby losses, the stack (exhaust) temperature from the furnace is still very high and the combustion efficiency is still only 80%. Furnaces and boilers claiming seasonal efficiencies of 90 to 95% are now available and these could do much to reduce the combustion losses inherent in standard furnaces. These furnaces operate on the principal of cooling the hot exhaust gases to the point where water vapour in the gases will condense, hence, these furnaces are frequently referred to as condensing furnaces.

Because the exhaust gases are relatively cool, they are usually discharged through the wall of the house via small diameter plastic pipe, eliminating the need for a chimney. As they also have electronic ignition, standby losses are virtually eliminated. These units thus have the potential to save approximately two-thirds of the energy lost up the chimney in a standard furnace installation.

4.2.3.4 Outdoor Furnaces

An outdoor furnace (or boiler) is one which is installed outside the heated envelope of the house and does not take its combustion air from the house, nor does the furnace chimney open into any part of the heated envelope. When combined with spark ignition, these units would eliminate pilot and thermosiphon losses although their location in unheated areas would increase casing losses, thus offsetting some of the savings. Because combustion air would be supplied directly from outdoors, infiltration could be minimized.

One outdoor furnace now on the market is designed to operate at the point where the exhaust gases are only slightly above their dew point. This furnace should therefore be more efficient than a standard furnace, although not as efficient as a condensing furnace.

The effect of outdoor or isolated furnaces impacts several of the preceding conservation opportunities. Their impact has been factored into infiltration, high efficiency furnaces and reduction of standby losses.

4.2.4 More Efficient Application

As knowledge increases and technology improves, it is expected that heating equipment will be more closely matched to loads, and controls will be more accurate, eliminating undesirable temperature fluctuations, resulting in greater efficiencies. Losses due to inefficient application (usually oversizing) and control are effectively part of standby losses and are treated as such in this analysis.

As other energy conservation measures such as improved insulation and glazing levels come into play, the size of heating equipment required is reduced. Smaller equipment has smaller combustion losses and frequently requires smaller chimneys and combustion air ducts, thereby reducing standby losses. Thus combustion losses can be reduced almost proportionally with building heat losses.

4.2.5 Lifestyle Changes

The simplest means of energy conservation is to turn down the thermostat and maintain a lower temperature in the home. Temperature setbacks result in savings that are a percentage of the energy used without setback and as energy used declines as weatherization improves, the impact of setback will decline.

Another lifestyle change is related to housing size and style. A trend from a predominance of single family dwellings to more energy efficient row housing, or to smaller dwellings, would tend to reduce energy use per account. These factors are considered to be beyond the scope of this report.

5. FACTORS AFFECTING PENETRATION

All existing and future housing built to less than optimum insulation levels offers an opportunity for energy conservation through upgrading toward the optimums.

Since housing has been built to different insulation standards over the years, conservation opportunities vary depending on year of construction. Opportunities also vary with dwelling style, as row houses usually have less surface area exposed to the weather than do single family dwellings. Demolitions of older, less well insulated dwellings would also constitute a conservation measure as replacement dwellings are more likely to be better insulated.

Future housing will be built to no less than 1980 standards and possibly significantly better. As 1980 standards are better than previous standards, the addition of new housing built to these standards will serve to raise average R values and thus reduce average heating consumptions, even if no action is taken to upgrade existing housing.

Retrofitting or building to optimum insulation levels will neither be immediate nor total. It is expected that there will be a gradual upward trend in insulation levels in both existing and new housing, influenced by the following factors:

5.1 Financial Motivation

Financial considerations can act as both a driving force and a restraint on more energy efficient buildings. Added costs combined with high mortgage rates could induce builders and buyers to try to cut costs at the expense of energy efficiency. These same constraints could also induce a trend to smaller housing, resulting in reduced consumption due to reduced size.

Financial considerations are also a variable factor depending on ownership of the dwelling. There is a definite relationship between owner occupancy and a willingness to spend money, while in rental accommodation there is little incentive for the landlord to invest in energy efficiency and even less for the tenant. There are several financial factors to be considered:

5.1.1 Rate Structures

Higher natural gas prices will promote energy efficiency in both new and existing buildings, particularly where owner occupied. In rental accommodation, where the tenant pays for heat, high consumption resulting in high heating costs may make it more difficult to rent the premises, thus encouraging the building owner to upgrade or build more efficiently.

5.1.2 Tax Incentives

There is an indirect tax incentive to the home owner or tenant paying his own heating bills to reduce energy consumption in that whatever money he saves is not taxable. If, on the other hand, a builder or a landlord can realize additional profits from an energy efficient building, either in the form of rental revenue or capital gains from the eventual sale of the property, such profits are taxable. In this case then, investments in energy saving features are less attractive.

Currently, insulation materials, storm and multiglazed windows and some other energy conservation materials are exempt Federal and Provincial sales taxes. This reduces material costs but provides relatively little in the way of incentives.

Tax incentives could be used to further energy conservation in all dwellings and could include the following:

(a) making a portion of mortgage interest payments tax deductible if the house is built to certain specified insulation and glazing standards;

(b) allowing owners of rental accommodation an accelerated capital cost writeoff on costs incurred in making the building more energy efficient.

5.1.3 Favourable Financing

Just as high mortgage rates discourage incurring added construction costs, low interest rates provided by governments or utilities to finance energy conserving features would encourage these investments.

Some favourable financing programs are already in place: the CHIP (Canadian Home Insulation Program) and COSP (Canadian Oil Substitution Program), both of which provide taxable grants to insulate (CHIP) or switch to a fuel other than oil (COSP); and the B. C. Hydro Low Interest Loan Program. All are continuing to prove their effectiveness. (Note: COSP is not an <u>energy</u> conservation program, it is an <u>oil</u> conservation program.)

The CHIP program is restrictive in that it is only available for homes built before 1961* and the money cannot be applied toward upgrading windows. Expansion of this program to cover post 1961 construction and to pay

* In early 1982, CHIP was expanded to include housing built up to 1971. This is expected to have a positive effect on conservation in housing built from 1961 to 1970.

for improved glazing and/or increasing the amount of the grant would result in even more widespread retrofitting and reductions in energy use.

An increase in the amount of money available to the borrower under the B. C. Hydro Loan Program (currently $500.00 maximum, which barely covers the cost of a few average size storm windows) would also spur such home energy efficiency improvements.

The Government of Saskatchewan, in cooperation with the Saskatchewan Power Corporation and Saskatchewan Housing Corporation have instituted (1 May 1981) a Home Energy Loan Program (HELP) providing a $3,000 interest free loan, repayable over 10 years to the first owner-occupier of a newly constructed energy efficient home providing these homes are built to meet certain technical standards. Such a program is expected to generate considerable interest in building energy efficient homes.

5.2 Regulatory Requirements

The opinion has been expressed in some circles that the best way to achieve energy conservation with insulation is to legislate it. However, there is no agreement as to what levels of insulation should be legislated or how it is to be accomplished or enforced. Also, while high insulation requirements could be mandated for new construction, there is a large inventory of existing housing that would be below these levels and could not economically be brought up to these levels.

At present, in new construction, there is only a small difference between practice and the optimum for gas heated homes in the Lower Mainland. Practice is R 20/12/D while optimum is R 28/20/D* (in the order ceilings/walls/windows; D = double glazed). Regulations requiring R 28 in the ceiling should meet with almost no resistance from home builders. R 20 walls involve some deviation from traditional 2 x 4 stud wall construction and mandating this value may incur some hostility. However, since there are various methods available to achieve this level it should be relatively easy to overcome any objections.

In any event, additional insulation, whether mandated or voluntary, would have the effect of reducing average heating energy consumptions and the effect would become more noticeable as more new housing stock, built to these standards, came into existence.

* Optimum levels as determined in 1978. See footnote on Page 12.

5.3 Promotional Base

An educated and informed public could provide the greatest impetus toward energy efficient housing. The public, being the "consumer" of this housing, has a vested interest in it being energy efficient. Unfortunately, the public is probably not as aware of energy issues as it should be. Advertising, radio and television programs, educational seminars and lectures would all serve to make the public aware of the need for and advantages of more energy efficient housing. Once the public starts to demand energy efficient housing, developers and builders will provide it, while owners of existing homes will be more inclined to upgrade them.

6. SATURATION - PENETRATION TOWARD OPTIMUMS

Two parallel factors must be considered when estimating the degree of saturation or penetration to optimum insulation levels - the percentage of housing upgraded and the percentage of optimum levels to which it is upgraded. These factors can be combined into a single number and expressed as the ratio of achieved reductions in U values to achievable reductions if optimum levels of insulation were used.

6.1 Possible Penetrations

It is impractical to expect all existing housing to be upgraded to optimum levels, nor is it likely that there will be an immediate move to optimum levels in new housing.

Similarly, it is known that existing housing is being upgraded to some extent and that some new housing is being built to better than 1980 acceptable standards.

Therefore, the actual degree of penetration to optimum and the resultant energy savings will be somewhere between zero and 100% and will be influenced by several factors.

Engineers from the Energy Use Engineering Department of B. C. Hydro with a knowledge of home insulation standards and trends, etc. debated the extent of penetration toward optimum levels to arrive at a concensus as to likely penetrations to optimum.

Factors considered were:

- age of housing, there being more incentive to retrofit houses built prior to 1961, as they have the least insulation and also are eligible for the CHIP grant;
- relative ease of insulating ceilings, relative difficulty of adding insulation to walls;
- relative expense of upgrading windows.

Local insulation contractors were contacted in an effort to ascertain what levels of insulation were being achieved (i.e. what householders were requesting or accepting). Glazing contractors and window manufacturers were contacted to ascertain the extent of use of double glazing and storm windows.

To estimate the extent and timing of penetration toward the optimums, a form was prepared to obtain estimates of the percentage approach to optimum insulation levels from current

levels for four forecast years. Provision was made to estimate trends for each type of dwelling and each of the three major elements being considered.

In accordance with standard forecasting practice, estimates were made of pessimistic, optimistic and probable degrees of optimization.

6.1.1 Pessimistic Forecast

The pessimistic forecast is predicated largely on existing circumstances of relatively low energy prices, minimal insulation codes, modest financial incentives and present levels of conservation promotion. It was assumed that energy prices would rise slightly faster than the average inflation rate over the long term, thus providing a modest economic incentive to conserve.

6.1.2 Optimistic Forecast

The optimistic forecast is based on a movement of energy prices to replacement costs, generous incentives (low interest loans, grants, etc.) to homeowners and homebuilders to upgrade insulation levels and energetic involvement by governments and utilities in promoting energy conservation, as well as revised building standards requiring more insulation.

6.1.3 Probable Forecast

The probable forecast falls between these two and represents a compromise between the two extremes. It is based on energy prices increasing slightly faster than the general inflation rate thus providing a financial incentive to conserve, greater public awareness of the need to conserve, (resulting from increased advertising and promotion) the continuance of government incentive programs to improve existing housing (i.e. CHIP), somewhat more exacting building codes combined with increasing acceptance of present B. C. Hydro insulation recommendations (i.e. optimum levels) on the part of the home building industry and the buying public.

6.2 Theoretical Limits

From an engineering point of view, there are two additional penetrations which define the theoretical limits of this study. These are zero penetration and saturation or 100% penetration.

6.2.1 Minimum or Zero Penetration

If no changes were made to existing housing, thus maintaining average heating consumption for this housing at its 1980 level and all housing built after 1980 were built to 1980 standards, (which are better than the average levels in the existing stock, but less than optimum), there would be a reduction in average consumption due to dilution of the old stock by the addition of new stock. Minimum penetration therefore represents the future effects of conservation efforts to date.

6.2.2 Maximum Penetration

Saturation would result if all existing homes were retrofitted to, and all future housing were built with optimum insulation levels. Maximum penetration therefore delineates the theoretical maximum conservation attainable with improved insulation and glazing levels.

An intermediate step in saturation would occur if existing housing were left unchanged, but all future housing were built to the optimum.

6.3 Oil-to-Gas Conversions

As stated in Section 2.4, oil-to-gas conversions are assumed to be pre-1960 housing. Therefore, conversions during each five year period in the study, have been subtracted from the number of new accounts for that period and treated as a separate pre-1960 housing stock.

Since all the same factors apply to this housing as apply to existing gas heated housing of similar vintage, the penetration of retrofit measures in this housing will be the same as for existing pre-1960 housing.

7. ANALYSIS AND RESULTS

For purposes of this analysis, the average natural gas heating account has been broken down into seven heat loss components. These are:

- ceilings
- walls
- windows
- miscellaneous elements (basements, floors, slab edges, etc.)
- infiltration and exhaust
- combustion losses;
- furnace standby losses.

The first three elements, namely, ceilings, walls and windows account for roughly two thirds of the heat loss and have similar characteristics; consequently, they are treated together. A summary was also prepared, which separates the effect of old housing, new housing and conversions.

7.1 Ceilings, Walls and Windows

A computer program was developed (by Energy Use Engineering, B. C. Hydro) and used to determine the reductions in energy consumption through these three elements as a result of improved levels of insulation and glazing. A flow chart of the computer program is contained in Appendix V.

Because of availability of data, calculations were performed in detail for:

- each of four forecast years: 1985, 1990, 1995 and 2005;

- two regions:

  Metro
  Fraser Valley

- three types of dwellings:

  single family, detached
  row housing
  other (mobile homes, etc.)

- three building elements:

  ceilings
  walls
  windows

- three levels of penetration to optimum:

  pessimistic
  probable
  optimistic

- two extreme situations:

  zero penetration (no retrofitting of existing housing, new housing built to 1980 standards only, no penetration to optimum)

  saturation (complete retrofitting of all existing homes to optimum, all new housing built to optimum)

- three scenarios:

  conservation from improvements to existing housing only
  conservation from improvements to new housing only
  effect of conversions from oil to natural gas.

The basic formula for energy saved due to improving the insulation of an element is:

$$S = A.F\ (U_{av} - U_1)$$

where S = saving

A = area of element

F = saving factor (includes an efficiency factor)

U_{av} = average U value before improvement

U_1 = U value after improvement

However, since our analysis is based on a percentage of penetration to optimum insulation levels,

$$U_{av} - U_1 = P(U_{av} - U_o)$$

where U_o = optimum U value

P = percentage penetration to optimum, expressed as a decimal

and the equation for savings becomes:

$$S = A.F.P\ (U_{av} - U_o)$$

Savings determined by the above equation are summed over different elements, year of construction, region or forecast year to produce the individual results.

New accounts with better than average insulation levels will exhibit positive savings. Oil-to-gas conversions, which are assumed to be pre-1960 housing, will be new accounts with less than average levels of insulation and will exhibit apparent negative savings until retrofit measures bring them above 1980 average levels.

7.1.1 Average Areas and "U" Values

The computer program was also used to calculate the average U values (U_{av}) and areas (A_{av}) of ceilings, walls and windows in each region for the 1980 base housing stock.

These average values are listed in Table 6 and were used to determine the breakdown of the heat losses from the average home, as shown in Figure 2.

Region/Element		Ceilings	Walls	Windows
Metro	U_{av}	.105	.153	1.08
	A_{av}	1167	1336	205
Fraser Valley	U_{av}	.099	.125	1.07
	A_{av}	1089	1256	199

Table 6: Average Areas and "U" Values of Ceilings, Walls and Windows - 1980 Building Stock

7.1.2 Typical Penetration Table

Table 7 is a typical penetration table showing the degree of penetration toward maximum savings available by upgrading from the 1980 average level of insulation to the optimum, expressed as a percentage.

Separate tables are generated for each forecast and forecast year.

For example, Table 7 indicates that by 1985, the ceilings of pre-1960 single family dwellings will be improved by 10% of the maximum, those built between 1960 and 1978 will be improved by 5% and those built between 1978 and 1980 will be improved by 10%. 80% of the houses built after 1980 are expected to follow the recommendations of building to optimum (R28).

Due to definite similarities between existing and optimum levels of insulation and climate (i.e. degree days), both regions have been combined for purposes of the penetration tables as it is logical that buildings with similar levels of insulation in areas with similar climates will experience similar degrees of improvement. Complete weatherization penetration tables are included in Appendix IV.

Indicates accepted standard practice in houses built 1978-80, e.g. 20.12D refer to R 20 in the ceiling, R 12 in the walls and double glazed windows.

Indicates that ceilings of single family dwellings built 1980-85 will be better by 80% of the maximum possible savings available by optimizing ceiling insulation.

FORECAST YEAR ,1985

YEAR <		1960	1970	1975	1978	1980	1985	1990	1995	2005
STYLE		7.0S	7.7S	10.7S	12.10S	20.12D				
SINGLE FAMILY DWELGS	CEILG	10	5	5	5	10	80	0	0	0
	WALLS	15	0	0	0	2	35	0	0	0
	WNDWS	7	3	3	3	8	100	0	0	0
APTS	CEILG	0	0	0	0	0	0	0	0	0
	WALLS	0	0	0	0	0	0	0	0	0
	WNDWS	0	0	0	0	0	0	0	0	0
ROW HOUSING	CEILG	5	2	2	2	2	75	0	0	0
	WALLS	3	0	0	0	0	15	0	0	0
	WNDWS	1	1	1	2	2	100	0	0	0
OTHER	CEILG	5	2	2	2	0	70	0	0	0
	WALLS	3	0	0	0	0	10	0	0	0
	WNDWS	1	1	2	2	5	65	0	0	0

Table 7: Sample Penetration Table - Percentage Approach to Optimum Weatherization Savings

7.1.3 Results of Weatherization Improvement

Table 8 shows sample results for Metro 1985 probable forecast. Similar results were generated for both regions and all forecasts but not included in this report due to their bulk.

Summary results showing improvements from retrofitting pre-1980 homes, the effect of conversions and from building newer homes to better standards are shown in Appendix VI. Results for the three forecasts, probable, pessimistic and optimistic and for the two theoretical limits, namely maximum and minimum penetration are included.

PROBABLE FORECAST - 1985

Metro - Gas Heating

Reduction in Energy Demand Therm/year				
	Ceiling	Walls	Windows	Total
Single Apartments Row Housing Other	3.60228E+06 0 258815 78513.1	1.47741E+06 0 375318 104851	3.87570E+06 0 484336 243691	8.95539E+06 0 1.11847E+06 427056
Total	3.93960E+06	1.95758E+06	4.60373E+06	1.05009E+07
Average Energy Reduction/Heating Account= 53.399 Therm/year Average Energy Reduction/Residential Account= 53.399 Therm/year				

Table 8: Sample Weatherization Results
Metro, Probable Forecast, 1985

Table 9 shows overall weatherization results, on a regional and total basis as well as the reduction as a percentage of 1980 base year use. Reductions are normalized to space heating use per heating account.

BASE YEAR (1980) Average gas space heating consumption per account = 849 Therms/yr

Region / Forecast	1985 Pes.	1985 Prob.	1985 Opt.	1995 Pes.	1995 Prob.	1995 Opt.	2015 Pes.	2015 Prob.	2015 Opt.
Gas Therms/Yr.									
Metro - Old	17	33	47	40	80	138	77	122	173
- New	12	45	87	154	160	164	215	224	224
- Conv.	-37	-25	-15	-20	4	20	-4	15	46
- Total	26	92	99	173	247	304	288	361	443
Fraser - Old	9	17	43	25	41	81	40	62	87
Valley - New	71	76	79	125	134	138	251	267	269
- Conv.	-27	-19	-14	-25	-6	7	-9	5	21
- Total	57	74	108	125	221	276	282	333	377
All Hydro - Old	14	27	58	34	64	114	61	92	134
- New	53	57	59	143	152	154	231	244	247
- Conv.	-29	-22	-15	-22	0	14	-4	10	31
- Total	38	61	103	154	221	304	288	351	411
% Reduction	4	7	12	20	29	36	31	41	48

Table 9: Annual Reduction Due to Weatherization per Natural Gas Space Heating Account - Therms/yr

As mentioned before, the negative values shown for conversions indicate that these conversions will tend to increase the average use per account. Not until 1995 when a large percentage of these accounts has been retrofitted will they show some conservation effect (as compared to average 1980 consumption).

7.2 Miscellaneous Elements

It is estimated that a 60% reduction in miscellaneous losses could be realized by insulating miscellaneous elements to their optimum levels.

An estimate of penetrations to optimum was prepared and reductions calculated for miscellaneous heat losses and these are contained in Table 10.

1980 base year consumption/account = 849 therms/yr
Consumption assigned to miscellaneous elements = .10 x 849 = 85 th/yr
Conservation potential = 0.6 x 85 = 51 th/yr
Effect at the furnace = $\frac{51}{0.8*}$ = 64

	1985			1995			2005		
	Pes	Prob	Opt	Pes	Prob	Opt	Pes	Prob	Opt
% Penetration	5	10	20	10	20	30	25	40	60
Reduction in misc losses per gas heating account therms/yr	3	6	13	6	13	19	16	26	38

* 80% combustion efficiency; i.e. a reduction in furnace output to provide for this loss will also save the combustion losses associated with producing that output.

Table 10: Reduction in Miscellaneous Heat Losses

7.3 Infiltration

As previously stated, infiltration can be reduced 50% with weatherstripping, caulking and better air-vapour barriers, while air-to-air heat exchangers can be used to recover a further 21%. These are optimal reductions; actual reductions will be percentage of these values.

7.3.1 Reduced Infiltration Through Better Seal of the House

Optimum reductions through more airtight housing are as follows:

1980 base year space heating usage = 849 therms/yr
1980 infiltration loss = .14 x 849 = 119 therms/yr
Weatherstripping potential reduction = .5 x 119 = 59.5 therms/yr
Effect at the furnace = $\frac{59.5}{.8*}$ = 74 therms/yr

* 80% combustion efficiency; i.e. a reduction in furnace output required to heat infiltration air will also save the combustion losses associated with producing that output.

Table 11 is the penetration table for improved air tightness.

Forecast Year	1985			1995			2005		
Year of Construction	Pes	Prob	Opt	Pes	Prob	Opt	Pes	Prob	Opt
Pre 1980	2	5	10	6	12	20	10	15	25
80-85	10	15	20	10	15	20	15	25	35
85-90	-	-	-	15	25	35	20	30	40
90-95	-	-	-	25	40	50	25	40	50
95-2005	-	-	-	-	-	-	40	60	70

Table 11: Improved Weatherstripping Penetration

The improvements expected from weatherstripping are the summation of improvements to each generation of housing, i.e. in 1985, the probable forecast is for a 5% improvement in all pre-1980 housing and a 15% improvement in housing built in 1980-85. Thus,

$$\frac{74}{317,550}\ [(.05)(278,971^{**}) + .15(38,579)] = 5 \text{ therms/yr per account.}$$

** These 278,971 accounts consist of the 242,221 accounts on record in 1980, plus 36,750 conversions expected between 1980 and 1985. 38,579 new houses are expected to be added in this same time period.

A summary of the savings expected from weatherstripping is contained in Table 13.

7.3.2 Reduction in Losses Due to Air-to-Air Heat Exchangers

Effective reductions through the use of air-to-air heat exchangers are determined as follows.

1980 base year space heating consumption
= 849 therms/account
1980 infiltration loss = 119 therms/account
Air-to-air heat exchanger potential recovery
= 0.3 x 119 x 0.7 = 25 therms/account
Effect at the furnace = $\frac{25}{.8}$ = 31 therms/account

Table 12 is the penetration table for air-to-air heat exchangers. Savings are calculated in the same manner as for weatherstripping, with results shown in Table 13.

Forecast Year	1985			1995			2005		
Forecast	Pes	Prob	Opt	Pes	Prob	Opt	Pes	Prob	Opt
Pre 1980	0	0	0	0	0	0	0	2	5
80-85	0	0	0	0	0	0	0	0	0
85-90	-	-	-	0	0	.5	0	0	.5
90-95	-	-	-	0	.5	1	0	.5	1
95-2005	-	-	-	-	-	-	0	5	10

Table 12: Air-to-Air Heat Exchanger Penetration

1980 base year space heating usage = 849 therms/account
1980 infiltration loss = 119 therms/account
Potential savings due to heat exchangers = 31 therms/account
Potential savings due to weatherstripping = 74 therms/account

Year	1985			1995			2005		
	Pes	Prob	Opt	Pes	Prob	Opt	Pes	Prob	Opt
Weatherstrip	2	5	8	7	13	19	14	21	29
Air-to-Air Heat Exchanger	0	0	0	0	0	0	0	0	1
Total	2	5	8	7	13	19	14	21	30
% of 1980 Base	<1	<1	1	1	2	2	2	2	4

Table 13: Annual Energy Reductions Due to Improved Weatherstripping and Use of Air-to-Air Heat Exchangers - therms/yr Per Heating Account

7.4 Improvements in Heating Equipment Efficiency

As stated in Section 4.2.3, more efficient equipment such as vent dampers, spark ignition, condensing furnaces and outdoor or isolated furnaces can reduce energy consumption.

However, measures taken to reduce building heat loss will reduce the size of heating equipment required (or the demands on existing equipment in a retrofit situation). A reduced need will result in a corresponding reduction in combustion losses, although it may also result in increased standby losses due to the heating equipment being on "standby" a greater percentage of time. Such increases would be small and have been factored into the reductions due to spark ignition and vent dampers (clause 7.4.2).

Table 14 contains a summation of reductions in energy requirements due to improvements in the building envelope and the estimated gas requirements with conventional heating equipment.

These reduced requirements are then used to determine the savings possible due to using more efficient furnaces.

7.4.1 Condensing Furnaces

The Energy Use Engineering Department of B. C. Hydro began monitoring six condensing and four outdoor furnace installations in early 1982, but it will be 1983 before any conclusive results are available as to seasonal efficiencies under lower mainland conditions. Therefore, we have assumed that seasonal efficiencies will be at the lower limit of manufacturers' claims, i.e. 90%; thus, the 31% combustion and standby losses could be reduced to 10%. So it could be assumed that potential savings due to high efficiency furnaces are roughly 20% of projected energy requirements with standard furnaces. Potential savings are also listed in Table 14.

1980 base year consumption = 849 therms/account
1980 Combustion & standby losses = 0.31 x 849 = 263 therms/account

Forecast Year	1985			1995			2005		
Forecast	Pes	Prob	Opt	Pes	Prob	Opt	Pes	Prob	Opt
Ceilings, walls and windows	38	61	103	174	236	304	289	351	411
Miscellaneous	3	6	13	6	13	19	16	26	38
Infiltration	2	5	8	7	13	19	14	21	30
Total	43	72	124	187	262	342	319	398	479
1980 Base	849	849	849	849	849	849	849	849	849
Future Heating Requirement	806	777	725	662	587	507	530	451	370
20% Potential Savings	161	155	145	132	117	101	106	90	74

Table 14: Potential Savings With High Efficiency Furnaces - Therms/year

Any savings due to improved combustion efficiency will be related to the reduced consumption level, rather than the 1980 level. For example, by 1985 it is probable that improvements to old housing, combined with the diluting effect of new construction will result in an average reduction per account of 72 therms/yr and that the average account with conventional furnaces in 1985 will therefore consume 777 therms/yr for space heating, as compared to 849 therms/yr in 1980. Since this consumption level is with a standard furnace and a condensing furnace saves approximately 20% of this requirement,

potential savings with condensing furnaces would be 155 therms/year and would decline as future heating requirements decline.

Table 15 is the penetration table for high efficiency furnaces. Since gas furnaces have a fairly long life span, very few existing furnaces are expected to need replacing in the next few years. Installations in new housing are expected to increase each year as energy prices go up and competition among manufacturers brings the price of these furnaces down, and as home buyers start to demand this feature in new homes.

	1985			1995			2005		
Year of Construction	Pes	Prob	Opt	Pes	Prob	Opt	Pes	Prob	Opt
Pre 1980 Stock	0	.5	1	.5	1.5	3	1	2	5
80-85	0	.5	1	0	.5	1	0	.5	1
85-90	-	-	-	2	5	10	2	5	10
90-95	-	-	-	10	20	30	10	20	30
95-2005	-	-	-	-	-	-	20	30	40

Table 15: Penetration of High Efficiency Furnaces

Savings are calculated in the same manner as for infiltration using the potential savings for each forecast and forecast year, with results included in Table 17.

7.4.2 Vent Dampers and Spark Ignition

Table 16 is the penetration table for spark ignition and vent dampers and is used to calculate energy savings with these options in the same manner as infiltration, with results included in Table 17. The potential savings for these devices is 70 therms/year.

	1985			1995			2005		
Forecast	Pes	Prob	Opt	Pes	Prob	Opt	Pes	Prob	Opt
Pre 1980	0	.5	1	2	4	6	10	20	30
80-85	0	.5	1	2	4	6	10	20	30
85-90	-	-	-	10	20	30	15	25	35
90-95	-	-	-	15	30	50	20	35	55
95-2005	-	-	-	-	-	-	30	50	60

Table 16: Penetration of Vent Dampers and Spark Ignition

This feature will be competing with both standard (i.e. with pilot light and no damper) and condensing furnaces for the available market and therefore, the total penetration of the available options cannot exceed 100%. Since spark ignition and vent dampers are relatively inexpensive ($300 extra per furnace) and condensing furnaces are expensive ($2,000 - $2,500 extra), it is expected that the former will outsell the latter, resulting in greater market penetration.

1980 base year consumption = 849 therms/account

Forecast Year	1985			1995			2005		
Forecast	Pes	Prob	Opt	Pes	Prob	Opt	Pes	Prob	Opt
Savings from high efficiency furnaces therms/year	0	1	1	3	5	7	6	9	11
Savings from Spark Ignition & Vent Dampers	0	0	1	3	7	10	11	20	28
Total	0	1	2	6	12	17	17	29	39

Table 17: Savings Due to High Efficiency Furnaces, Spark Ignition and Vent Dampers - Therms/Year/Account

7.5 Overall Results

Savings from Tables 9, 10, 13 and 17 have been consolidated and totalled in Table 18.

Probable reductions in average residential heating consumption will range from 73 therms/yr per account in 1985, to 428 therms/yr in 2005. The reductions will be due primarily to improvements in ceilings, walls and windows, with minor contributions made from improvements to miscellaneous elements, infiltration and heating equipment efficiency. Conversions of old housing to gas heating will have a negative effect initially (i.e. an increase in consumption), as they are insulated to less than the average 1980 levels on which this study is based.

1980 base year space heating consumption per account (Average for Lower Mainland) = 849 therms.

Forecast Year	1985			1995			2005		
Forecast	Pes	Prob	Opt	Pes	Prob	Opt	Pes	Prob	Opt
Ceilings	22	23	43	63	68	95	95	107	117
% *	3	3	5	7	8	11	11	13	14
Walls	20	33	39	59	88	100	85	115	133
%	2	4	5	7	10	12	10	14	16
Windows	25	28	36	75	80	93	115	118	129
%	3	3	4	9	9	11	14	14	15
Miscellaneous Elements	3	6	13	6	13	19	16	26	38
%	0	1	2	1	2	2	2	3	4
Weatherstrip	2	5	8	7	13	19	14	21	29
%	-	1	1	1	2	2	2	2	3
Air-to-Air Heat Exchangers	0	0	0	0	0	0	0	0	1
%	-	-	-	-	-	-	-	-	-
High Efficiency Furnaces	0	1	1	3	5	7	6	9	11
%	-	-	-	-	1	1	1	1	1
Spark Ignition & Vent Dampers	0	0	1	3	7	10	11	20	28
%	-	-	-	-	1	1	1	2	3
Total	72	96	141	216	274	343	342	416	486
%	8	11	17	25	32	40	40	49	57
Effect of Conversions†	-29	-23	-15	-23	0	16	-6	12	32
Net Reduction	43	73	126	193	274	359	336	428	518
%	5	9	15	23	32	42	40	50	61

* Percentage of base year consumption.
† See Clause 9.1

Table 18: Annual Reductions Per Residential Gas Heating Accounts - Lower Mainland - All Factors

8. DISCUSSION

Table 18 indicates that savings due to improvements to ceilings, walls and windows constitute approximately 80% of the total savings predicted for gas heated housing up to 2005. These primary elements have therefore been used as the basis for further study and analysis.

8.1 Analysis by Age of Dwelling

The detailed computerized analysis of the primary elements provides a breakdown of the effects of conservation measures in old and new housing and conversions. The effect of conversions was separated in Table 18 in order not to negate the true effect of conservation efforts on both existing pre-1980 gas heating accounts and new post-1980 construction.

Table 19 contains a summary of results of conservation efforts on the primary elements on the basis of old, new and conversion dwellings, normalized by the total number of accounts.

BASE YEAR 1980: Average gas space heating consumption per account = 848 Therms/yr

Region / Forecast	1985 Pes.	1985 Prob	1985 Opt.	1995 Pes.	1995 Prob	1995 Opt.	2005 Pes.	2005 Prob	2005 Opt.
Δ48 Therms/yr.									
Metro - Old	17	33	47	40	80	128	77	123	173
- New	43	45	47	154	162	164	215	224	224
- Conv.	-33	-25	-15	-20	4	22	-4	13	42
- Total	26	53*	99	173	247	324	288	360	440
Fraser - Old	8	17	43	25	41	81	42	63	97
Valley - New	71	74	79	175	184	188	254	267	268
- Conv.	-22	-19	-14	-25	-4	7	-8	6	24
- Total	57	74	108	175	221	274	288	335	378
All Hydro - Old	14	27	55	34	64	114	61	94	134
- New	57	57	57	167	173	174	234	244	245
- Conv.	-25	-27	-15	-23	0	16	-6	10	35
- Total	32	61	103	174	234	304	289	351	411
% Reduction	4	7	12	20	28	36	34	41	48

* This means that out of the predicted reduction of 53 therms/year/account, retrofitting of old pre-1980 homes contributed 33 therms, new homes helped reduce 1980 average by 45 therms and conversions, including their retrofitting, add 25 therms.

Table 19: Annual Reduction by Account Type Normalized by Total Accounts

8.2 Reductions Normalized by Account Type

All previous tables have expressed savings normalized over the total number of accounts, e.g. savings due to retrofitting old houses are averaged over all houses. Table 20 normalizes savings over the stock of the housing responsible for the saving, i.e. savings due to retrofitting old housing are averaged only over the old housing.

[illegible] YEAR 1980: Average gas space heating consumption per account = 838 Therms

Region / Forecast	1985 Pes.	Prob	Opt.	1995 Pes.	Prob	Opt.	2005 Pes.	Prob	Opt.
838 Therms/yr.									
Metro - Old	21	47	83	70	139	238	154	248	351
- New	494	527	547	540	562	577	553	571	580
- Conv.	-333	-175	-107	-161	21	163	-30	158	345
- Total	26	57	99	173	247	324	359	365	442
Fraser Valley - Old	12	33	58	51	84	144	119	130	247
- New	396	422	441	404	451	454	444	447	444
- Conv.	-303	-245	-197	-251	-53	72	-100	43	275
- Total	57	74	109	175	201	274	289	335	375
All Hydro - Old	19	35	74	63	119	211	140	223	310
- New	439	449	459	482	509	514	492	517	517
- Conv.	-254	-196	-128	-192	-1	130	-43	127	334
- Total	32	41	103	174	234	304	289	351	411

Table 20: Annual Reduction by Account Type

For example, it is probable that by 1985, the average pre-1980 dwelling will be improved to the point where it uses 35 therms less energy than the average 1980 consumption; new homes (built 1980-85) will use 468 therms less and conversions, which are assumed to be all pre-1960 housing and therefore rather poorly insulated, will use 196 therms more than the average.

By 2005, these conversions will have been retrofitted to the point where they are using 127 therms less than the 1980 average.

8.3 Minimum and Maximum Weatherization Effects

Table 21 contains the results from calculating the two theoretical extremes of weatherization. The minimum is the reduction due to no retrofitting of existing housing, with new housing built to 1980 standards, and indicates that average consumption per heating account will decline merely because housing now being built is more energy efficient than older housing.

The maximum reduction is the theoretical (but not necessarily practical), reduction obtainable if all existing housing and conversions were upgraded to, and all future housing were built with, optimum levels of insulation.

These values are useful to determine the additional potential savings available if total optimization of insulation and glazing could be realized.

BASE YEAR 1980: Average gas space heating consumption per account = 849 Therms/yr.

Region / Forecast		1985 Min.	1985 Max.	1995 Min.	1995 Max.	2005 Min.	2005 Max.
GAS Therms/yr.							
Metro	- Old	0	454*	0	340	0	291
	- New	40	49	136	166	186	228
	- Conv.	-40	86	-38	82	-33	70
	- Total	0	589	97	589	153	589
Fraser Valley	- Old	0	357	0	232	0	167
	- New	65	83	151	192	213	271
	- Conv.	-26	36	-37	51	-27	37
	- Total	39	476	114	476	187	476
All Hydro	- Old	0	417	0	295	0	235
	- New	49	62	142	177	198	248
	- Conv.	-35	67	-38	69	-30	55
	- Total	14	546	104	542	168	537

* This means that out of the total reduction of 589 therms/year/account for Metro houses, 454 therms/year/account is the result of retrofitting pre-1980 (old) houses to optimum.

Table 21: Reductions Due to Theoretical Extremes of Weatherization Normalized by Total Accounts - Therms/Yr

This table indicates that the maximum potential reduction could be realized from retrofitting existing houses to optimum, which is logical in view of the large number of old,

poorly insulated houses with gas heating. However, Table 19 indicates that it is probable that the bulk of the reduction in consumption will be due to the addition of new housing. The difference between maximum (Table 21) and probable (Table 19) equals the additional potential savings that could be obtained if total optimization of ceilings, walls and windows could be achieved. These are shown in Table 22.

Forecast Year	Housing Category	Per Account Reduction Therms/yr	Potential Total Energy Savings Therms/yr x 10^6
1985	Old	390	123.8
	New	5	1.6
	Conv	90	28.6
	Total	485	154.0
1995	Old	231	103.5
	New	5	2.2
	Conv	69	30.9
	Total	306	137.1
2005	Old	139	78.4
	New	4	2.3
	Conv	43	24.3
	Total	186	105.0

Table 22: Potential Natural Gas Residential Heating Energy Savings Available Between Probable and Maximum Penetration - Lower Mainland

9. CONCLUDING REMARKS

This report examines the effect of weatherization, weatherstripping air-to-air heat exchangers and more efficient equipment on potential space heating energy needs to 2005. The report was prepared, as a first attempt or approximation, independent from other studies such as solar effects, potential in lighting, domestic water heating and appliances.

The heating requirements of a home are interrelated in a complex way to all above effects. A reduction in lighting or appliances energy consumption would result in some decrease in internal heat gain or increase in space heating needs - i.e. decreased savings. However the decrease in savings on the heating requirements will be only a fraction of the savings from better lighting or more efficient appliances and does not reduce the value of these energy conservation measures.

On the other hand any potential for solar heating cannot be related to 1980 consumption but has to be related to future needs as determined from this study.

APPENDIX I

A Practical Method For Energy Conservation Impact Analyses

A PRACTICAL METHOD FOR ENERGY CONSERVATION IMPACT ANALYSES

INTRODUCTION

THE NEED

There is need for good estimates of the potential impact of various energy conservation alternatives. Such information is required for forecasting, planning, budgeting, setting priorities and selecting the most beneficial actions.

IDEAL IMPACT ANALYSES

Accurate impact analyses require reliable details on the number, type, capacity, usage characteristic and developments underway for each application and equipment involved throughout the province. Although much of this is available for many applications, such as heating, water heating and processes, much more needs to be continually surveyed and tabulated for ideal analyses.

Ideal analyses will be costly to obtain and will not be possible for a long time - in fact they may never be available because of the details involved.

A PRACTICAL METHOD

The next approach in developing practical impact analyses is to:

- Use the reliable information available in the B. C. Hydro PRODUCT SALES ANALYSIS on energy use-per-account for the customer groupings in both gas and electric services.

- Apportion the use-per-account to the major usages, such as for heating, lighting, motors, processes, etc., based on analyses of typical situations and experience.

- Give weightings to the various energy conservation actions possible in each main application of consequences, based on the present day average use-per-account for each major usage, expert information of the highly probable technical improvements within the next 25 years and judgment by the various specialists involved of the range of potential saturation resulting from the various major energy conservation actions.

The following charts summarize this approach, which we have developed as a practical method for energy conservation impact analyses.

INTERPRETATION OF DATA

The impact band varying from pessimistic to optimistic has value in indicating the range of impacts we can expect. The three values extracted from this range can be interpreted to mean:

Pessimistic, P

What we can expect with a continuation of past practice, with only a token energy conservation effort.

Probable, P

The most probable impact taking into account the changes we can expect with an increasing concern for energy conservation practices.

Optimistic, O

The best we can expect short of rationing and strict regulation.

FUTURE USAGE

Note that the potential energy conservation impacts are related to the present day (1980) per-account usage base. Should this information be applied to forecasting total future usage, allowances will be required for probable increased usage for:

- Increased conveniences, recreation and food production and productivity aids.
- Environmental amelioration.
- New applications such as electric and gas vehicles, industrial processes and off-peak heat-storage.

Energy conservation actions will have beneficial impact in also minimizing these additional usage needs.

SUMMARY

The approach herein should initiate a practical basis for systematically analyzing the potential impact of energy conservation alternatives, which can be periodically refined and updated as pertinent new information becomes available.

The approach herein provides the following key features:

1. Impacts are related to records of actual current usage in each application (e.g. the total savings are a percent of the current usage in each application).

Future impact updatings can similarly provide practical data by relating to future current records available on a monthly and annual basis for each region.

2. Impacts are coordinated to B. C. Hydro forecasts of future growth in number of accounts.

3. Impacts are coordinated to avoid misleading accumulations. For example, savings from solar and heat pump systems in future years relate to future better insulated buildings and savings in air conditioning relate to lower lighting watts/m^2 in the future.

4. Impact evaluation of each energy conservation alternative in each major electric and gas application in the B. C. Hydro service area is provided.

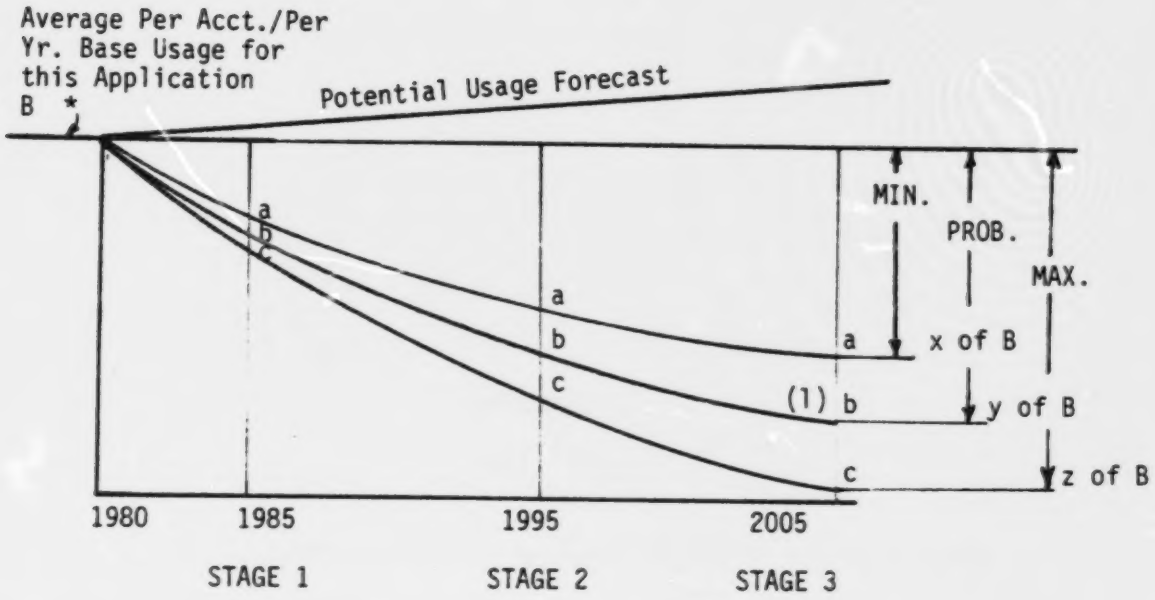
5. Impact evaluation of elements such as new developments, more efficient practices, retrofit, standards and marketing activity is provided.

6. B. C. Hydro electric and gas system totals are provided - impacts by region could be developed if required.

7. A systemized basis which can be adapted to also cover impacts on peak demands, revenues, capitalization and customer costs; impacts of new loads and impacts in each region is provided.

Because of the importance of sound impact evaluations to B. C. Hydro operations, plans are to extend and refine the impact analyses initiated herein to periodically provide updated information as required. Comments and suggestions will be appreciated.

A PRACTICAL METHOD OF ENERGY CONSERVATION IMPACT ANALYSIS



* For existing accounts B = average from billings
For new accounts B = present average for new additions in 1979/1980

METHOD

1. Identify the minimum, probable and maximum improvements possible with technical practicability in each application and account grouping by 1985, 1995 or 2005 as appropriate depending on the latest information available.

2. Apply potential minimum, probable, maximum impact on saturation for each EC action - for existing and new installations to locate points 1a, b, c; 2a, b c; 3a, b, c.

3. Apply the resultant reductions to the number of accounts to obtain pessimistic, probable and optimistic impacts for each application and account grouping to develop averages per account per year energy conservation impact curves corresponding to a, b, c above.

FIGURE 1A

APPENDIX II

Data Files

B. C. Hydro's Accounts by Dwelling Style and Fuel Types.

Average Areas of Typical Construction.

U Values of Building Elements at Optimum Insulation Levels.

B.C.Hydro's Residential Gas Heating Accounts by Dwelling Style
Total Accounts by Region

Year	1960	1970	1975	1978	1980	1985	1990	1995	2005
Metro - Gas Heating									
Single	48226	105864	129532	140788	143990	186818	221588	249043	291318
Apartments	0	0	0	0	0	0	0	0	0
Row Housing	497	706	1499	2387	4547	5900	6997	7865	9200
Others	994	2570	2039	2130	3031	3932	4665	5242	6132
Total Hts.	49717	109140	133070	145305	151568	196650	233250	262150	306650
Total Res.	49717	109140	133070	145305	151568	196650	233250	262150	306650
Fraser Valley - Gas Heating									
Single	10920	39774	65844	78322	76150	101556	127344	156030	216468
Apartments	0	0	0	0	0	0	0	0	0
Row Housing	120	305	1024	1746	1813	2418	3032	3715	5154
Others	960	3634	3551	4832	12690	16926	21224	26005	36078
Total Hts.	12000	43713	70419	84900	90653	120900	151600	185750	257700
Total Res.	12000	43713	70419	84900	90653	120900	151600	185750	257700

Total Hydro Accounts

Hts. Elec.	16380	25072	43344	75885	108302	166200	223400	278000	350000
Res. Elec.	360900	546700	732674	829240	882923	1033000	1223000	1319000	1435000
Gas Hts.	61717	152853	203489	230205	242221	317550	384850	447900	564350

****

The above table was copied from file GACCNT.DAT and edited to contain gas heating accounts only. Dec 23,1981. G.H.Pinch
Edited to agree with 1980 Long Range Gas Forecast from Gas Div.-Apr.6/82

AVERAGE AREAS OF TYPICAL CONSTRUCTION- SQ FT

Styles	Single	Apartments	Row Housing	Other
Ceiling	1200	190	560	500
Walls	1372	215	650	650
Windows	208	100	150	150

U values of Building Elements at Optimum Insulation Level
see data sheet H206

	Electric						Gas	
	Metro	F.V	C.I	N.C	S.I	V.I	Metro	F.V
Saving Factor F	38.38	38.38	68	47.5	48.59	37.4	1.9	1.9
Ceiling U(1)	.025	.025	.021	.021	.025	.025	.036	.036
Wall U(2)	.060	.060	.041	.041	.060	.060	.060	.060
Window U(3)	.38	.38	.28	.28	.38	.38	.59	.59

Entered by Zak El-Ramly and P. Anderson June 15/79

Calculated by G. Pinch.

C.I corrected to agree with H206 Sep. 13,1979 by Zak

Saving Factor calculated by Zak on July 30,1981
Saving Factor and Window U-value altered on July 30,1981 by G. Jung

APPENDIX III

Insulation Levels

H 205 - A Method for Calculating Optimum Levels of Insulation.

H 206 - Recommended Insulation Levels.

INTRODUCTION

The need to update insulation standards and to retrofit existing homes has become increasingly important due to world energy problems and increasing energy costs. As a result, various standards and recommendations for improved insulation levels have been developed. These regulations and recommendations are of necessity generalized, and tend to specify the minimum rather than the optimum. This data sheet presents a method for determining the economic optimum level of insulation for any individual situation.

DEFINING OPTIMUM LEVELS

The economic optimum level of insulation is that which would result in energy cost savings, over the life of the investment, of more than the initial cost of installing it.

The law of diminishing return applies to insulation; each added layer saves less than the one installed before. The analysis is done on a marginal (incremental) approach, i.e. every increment in "R" value has to be justified on its own. The last increment that breaks even is **the optimum level.** Since all preceding layers have higher savings, and usually the same unit cost, the overall scheme will always be economically profitable.

Factors that affect the optimum levels include:

— Weather pattern (usually expressed in degree days)
— Installed cost of insulation
— Cost of energy
— Cost of money (interest or mortgage rate)
— Fuel escalation rate
— Life time of the application

The last three factos — namely interest rate, fuel escalation rate and life time of the application can be replaced by the present worth factor.

ECONOMICS

The present worth is todays value of a stream of payments escalating at a certain rate in today's dollars.

The present worth factor is the present worth when the stream of payments is valued initially at one dollar.

For our purpose the stream of payments represent annual energy savings. When valued initially at one dollar, at todays' energy price, the present worth factor is given by

$$\text{p.w.f.} = a \cdot \frac{(a^n - 1)}{a - 1}$$

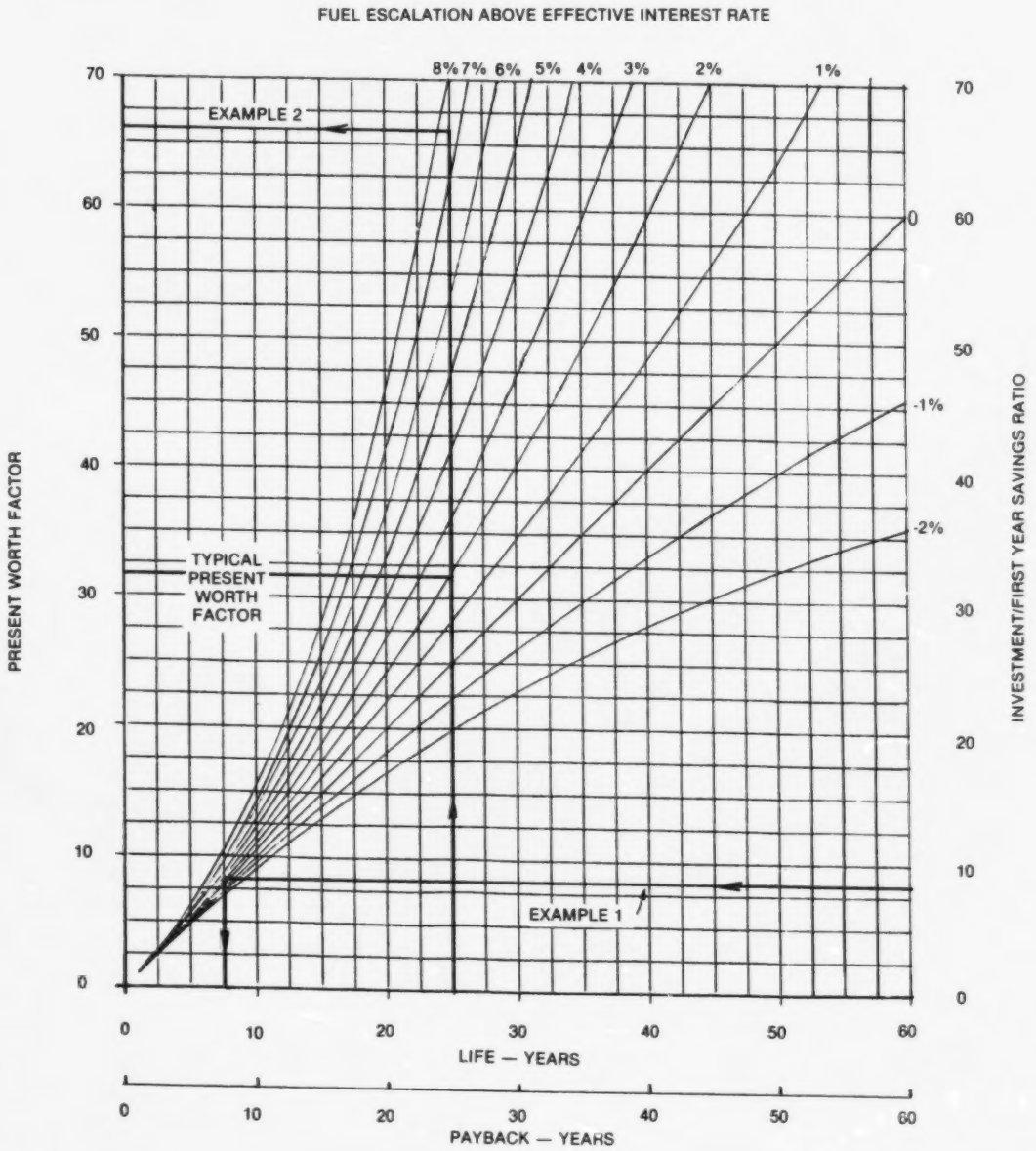
where

$$a = \frac{1 + f}{1 + i}$$

f = fuel escalation rate
i = effective interest rate (the interest you can get by investing, at present, in long term investment such as bonds, or the mortgage rate if financing is required).
n = number of years

The interest rate used must be the long term effective interest rate after allowance for taxes (or tax credit) and will depend on the individual's income level and other investment options available to him. The life time of the energy conservation device will also depend on the house age and hence will vary from one case to another.

To allow for these individual variations, Figure 1 is constructed. The Figure shows the variation of the present worth factor with number of years for several values of the difference between fuel escalation and interest rate (using the difference between the two rates is an approximation for simplicity; the approximation causes very little variation in the results).



TYPICAL PRESENT WORTH FACTOR

Figure 1: Present Worth Factor and Payback Period

Giving that a common mortgage life is 25 years and that energy cost is escalating at about 2% above interest (12% typical conservative fuel escalation and 10% for long term bonds and guaranteed investment certificates), Figure 1 shows that a typical present worth factor is about 31.4.

OPTIMUM LEVELS FOR A REFERENCE CASE

The optimum level of insulation depends on weather patterns, installed cost of insulation, cost of energy (including a heating system seasonal efficiency) and present worth factor.

A careful analysis of the effects of all these variables has been made in EUE Project 7839 (see references). This data sheet summarizes the results of the project and presents a simplified approach to calculating the optimum levels.

Figure 2 shows the variation of the optimum overall R value between studs with present worth factor for several initial costs of insulation for a reference case. The reference case is Vancouver (3031 Celsius degree days, gas heated home, $0.20/therm and 69% heating system relative overall efficiency). The figure applies for walls, roofs, ceilings, and exposed floors and shows the between the studs or joists value.

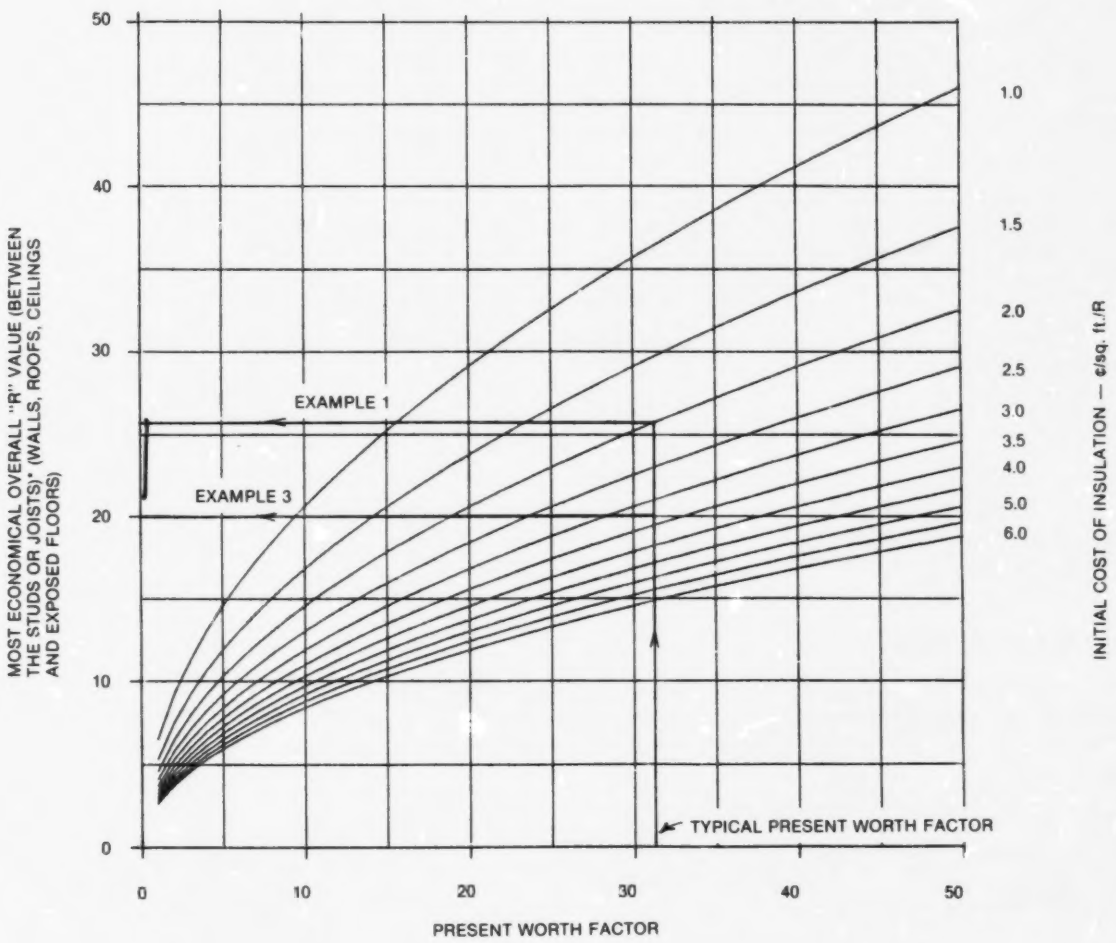


Figure 2: Variation of Optimum "R" with Present Worth Factor and Insulation Cost for Walls, Ceilings, Roofs and Exposed Floors

***Reference Base** — Vancouver, B.C. Gas Heating (April 1979) — Apply Adjustment Factor in Table 1 for Other Areas and/or Fuels

CORRECTION FOR OTHER REGIONS AND HEATING FUELS

For other regions and heating fuels, a multiplier K_r is used to correct the values obtained from Figure 2. The multiplier K_r has the approximate value given by:

$$K_r = \sqrt{\frac{C.D.D.}{3031} \times K_f}$$

where C.D.D. = Celsius degree days for the area

K_f = Heating fuel correction factor

$= \frac{\text{Gas Cost ¢/Therm}}{29 \times \eta}$ for **Gas**

$= \frac{\text{Oil Cost ¢/Gallon}}{49.37 \times \eta}$ for **Oil**

$= \frac{\text{Elect. Cost ¢/kW.h}}{\eta}$ for **Electric**

n = Relative overall efficiency (typically 0.69 for gas, 0.55 for oil, and 1.0 for electricity with in room resistance heaters)

Table 1 gives the K_r multiplier, at April 1979 energy cost, for representative cities in the five regions.

Table 1: Adjustment Factor for Optimum Levels of Insulation (April 1979 fuel prices)

REGION	Lower Mainland	Central Interior	North Coast	Vancouver Island	Southern Interior
City / Fuel	Vancouver	Prince George	Terrace	Victoria	Vernon
GAS	1.00	1.20	1.14	1.43	1.04
ELECT.	1.58	2.09	1.88	1.55	1.82
OIL	1.50	2.03	1.82	1.49	1.76

Note that the optimum overall R values are invariably higher for all regions and fuels than that for gas heated homes in Vancouver (the reference base). Standards on insulation usually recommend the minimum only. Since these standards are generalized across the province, the standard for gas heating in the Lower Mainland determines the minimum.

COST OF INSULATION

Table 2 includes some typical present-day costs of insulation and is intended as a guideline for calculating the optimum levels of insulation. Where required, actual costs can be obtained from local installers and suppliers. The relatively lower cost of insulating the attic can easily be seen.

Table 2: Approximate Cost of Insulation (1979)

Type of Insulation	Cost ¢/sq. ft./R
Batts & Loose Fill (Material only)	1.1 - 2.0
Batts & Loose Fill (Installed - Attic or New Walls)	1.6 - 3.5
Rigid Insulation (Material Only)	4.0 - 7.0
Blown In - Walls	4.0 - 8.0
Windows	**Cost $/sq. ft.**
Storm Windows (Installed)	$6.00 - $10.00
Double Glazed Windows (Installed)	$8.00 - $12.00

SAVINGS

How much is saved by insulating? Figure 3 shows the approximate savings for walls and ceiling for our reference base.

The figure can be used if the initial "R" value is nil, R7, R12 or R20. Enter the final overall "R" value (between the studs) on the horizontal axis then project vertically to intercept the corresponding curve for initial nominal "R" value. Read savings in $/1000 sq. ft. on the vertical axis.

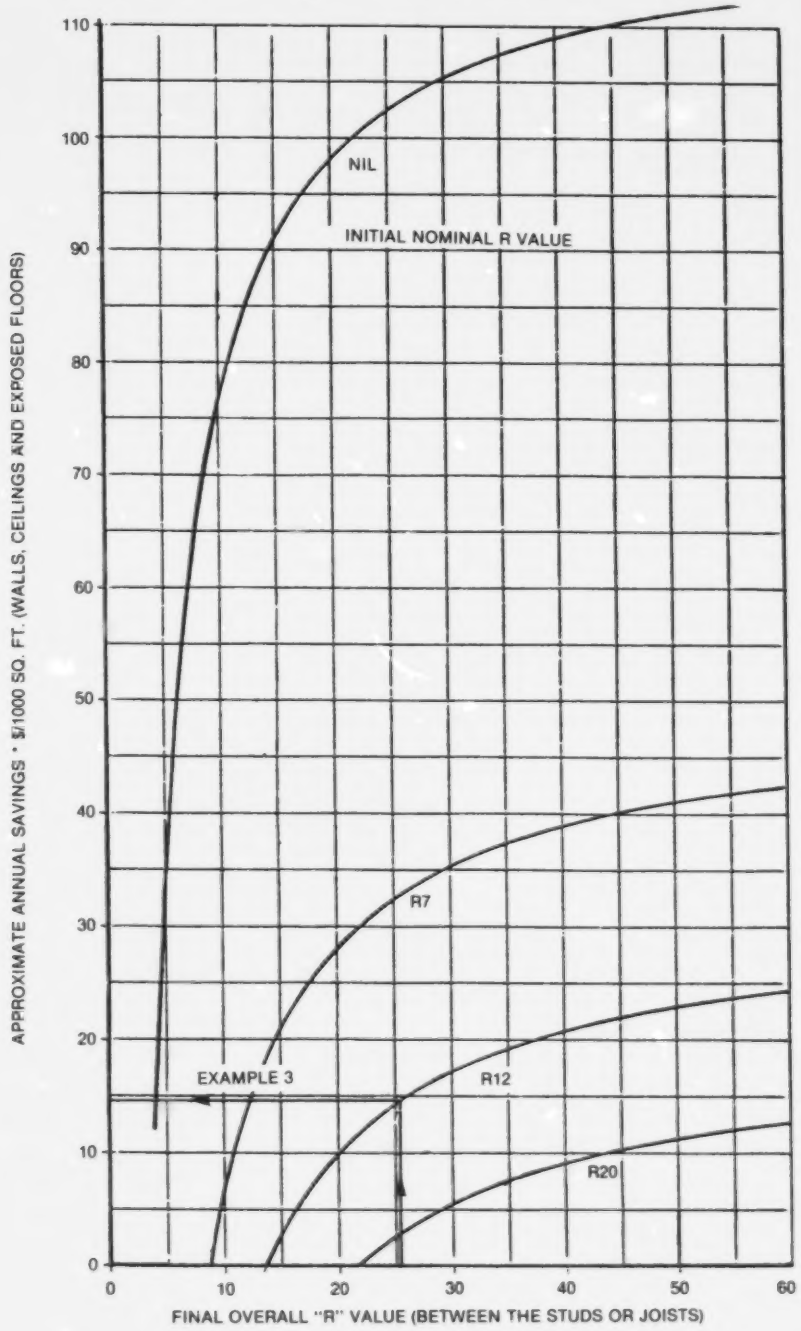


Figure 3: Annual Energy Saving Due to Increase in "R" Value (Reference Base — Vancouver, B.C. — Gas Heating April, 1979)

***Apply Adjustment Factors** in Table 3 for Other Areas and/or Fuels.

Table 3 gives the multiplier (Adjustment factor -K_S) to calculate the savings for the various regions and fuels. Like the optimum level, the savings also are always higher than for gas heated homes in the Lower Mainland.

Table 3: Adjustment Factor for Savings Calculations (April 1979 Fuel Prices)

REGIONS	Lower Mainland	Central Interior	North Coast	Vancouver Island	Southern Interior
City / Fuel	Vancouver	Prince George	Terrace	Victoria	Vernon
GAS	1.00	1.43	1.30	2.04	1.09
ELECT.	2.50	4.36	3.54	2.40	3.31
OIL	2.25	4.13	3.34	2.22	3.10

For areas other than those included in above table, the correction factor for savings is given approximately by:

$$K_S = \frac{\text{C.D.D.}}{3031} \times K_f$$

where K_f is the same as calculated before.

PAYBACK

How to calculate the payback period? After calculating the annual savings and the initial cost of the insulation, find the ratio initial cost/annual savings (I/S). Enter I/S on the right vertical axis of Figure 1. Move horizontally to intercept the assumed fuel escalation rate above interest then read the payback period on the horizontal axis (see example 1 at end for more explanation).

WINDOWS

For windows, Table 4 shows the potential savings from upgrading for the reference base. Table 4 is to be used in conjunction with Table 3, or the factor K_S to obtain the savings for other regions and fuels (actual saving is the product of the appropriate values from Tables 3 and 4).

Table 4: Potential Saving from Upgrading Windows and Maximum Economical Cost of Upgrading Windows (Reference base — Vancouver, B.C. — Gas Heating — April 1979)

(To be used in conjunction with Table 3)

From	To	Annual Savings $/sq. ft.	Max. Economical[1] Cost of Upgrading $/sq. ft.
Single[2] Glaze	Single & Storm	0.25	8.00
	Double Glaze[3]	0.22	6.85
	Double Glaze, Thermal Break	0.26	8.10
	Double Glaze & Storm	0.31	9.70
	Triple Glaze	0.31	9.70
	Triple Glaze, Thermal Break	0.33	10.55
	Quadruple Glaze	0.35	10.90
	Quadruple Glaze, Thermal Break	0.36	11.40
Double Glaze[3]	Double Glaze & Storm	0.09	2.85
	Triple Glaze	0.09	2.85
	Triple Glaze, Thermal Break	0.12	3.70
	Quadruple Glaze	0.13	4.10
Triple Glaze[3]	Quadruple Glaze	0.04	1.30

Notes:

1 — For a present worth factor of 31.4

2 — For wooden windows, reduce savings & maximum Economical Cost values by 15%

3 — Assuming 13 mm (½") airspace.

The maximum economical cost of upgrading in the case of windows is simply the annual savings multiplied by the present worth factor. The initial cost is thus recoverable within the assumed lifetime of windows. Table 4 also shows these maximum economical costs for a present worth value of 31.4 (corresponding to 2% fuel escalation above interest and 25 years). For other present worth factors, the savings calculated from Tables 3 and 4 are multiplied by the present worth factor obtained from Figure 1.

Maximum Economical Cost of upgrading = Annual Savings (Table 4)
x Adjustment Factor K_s (Table 3) **x p.w.f.** (Figure 1)

Window savings calculated above include only reduction in conduction heat loss. Multiple glazing usually results in reduced infiltration rates; the actual savings will be even higher. Moreover, it is difficult to attach a value to the increased comfort and quietness of the home which result from multiple glazing.

APPLICATION

Using the method described, Table 5 shows optimum overall levels of insulation for new frame-type homes for representative locations, at April 1979 energy costs.

Table 5: Optimum Levels of Insulation for Sample Locations

Element	Region / City / Fuel	Lower Mainland (Vancouver)	Central Interior (Pr. George)	North Coast (Terrace)	Vancouver Island (Victoria)	Southern Interior (Vernon)
Ceiling[1] & Exposed Floors[2]	Gas	28	33	32	40	29
	Electric	44	58	52	43	51
	Oil	42	57	51	42	49
Walls[3]	Gas	22	22	22	22	22
	Electric	22	32	32	22	32
	Oil	22	32	32	22	28
Glazing[4]	Gas	D.G.	T.G.	T.G.	T.G.	D.G.
	Electric	T.G.	Q.G.	Q.G.	T.G.	Q.G.
	Oil	T.G.	Q.G.	Q.G.	T.G.	Q.G.

D.G. — Double Glaze
T.G. — Triple Glaze
Q.D. — Quadruple Glaze

Notes:
1 — If practical — cost 1.7¢/sq.ft./R
2 — If space is available between floor joists — cost 1.7¢/sq.ft./R
3 — R 22 = R 20 between 2" x 6" studs,
R 28 = R 20 between 2" x 6" studs + 1¼" rigid insulation,
R 32 = R 20 between 2" x 6" studs + 2" rigid insulation — cost for rigid insulation 5¢/sq.ft./R.
4 — Assuming $3.50/sq.ft. for each additional layer of glazing.

More details on Hydro's new recommendation for "Energy Conservative Homes" are available in data sheet H 206. The "How To" is available in data sheet H 210.

Example 1. A 1200 sq. ft. gas heated home on Vancouver Island, present insulation level in the attic is R 7. What is the optimum level of insulation, how much will it cost to insulate to that level and what is the potential saving and the payback period?

Since no details are given about interest rate, we can use the typical present worth factor.

— **Cost** of batts or loose fill insulation (from Table 2) = **2¢/sq. ft./R**

— From Figure 2, the **optimum overall R value for the reference case (at 2¢)** = **27**

— From Table 1, the **correction factor for gas** = **1.49** (Vancouver Island)

— **Optimum overall R value:** 27 x 1.49 = R40 (corresponding to **R39 insulation**

— **Added insulation:** R39-R7 = **R32**

— Maximum added cost: R x cost/R x area
Maximum added cost: 32 x $.02 x 1200 = **$768**

— From Figure 3, **the saving** for the reference case = **$38/1000 sq. ft.**

— From Table 3, **the correction factor for savings K_S** = **2.04**

— **Total Savings:** $39 x 2.04 x $\frac{1200}{1000}$ = **$93**

— **Initial cost/annual savings** (I/S): $769/$93 = **8.25**

— From Figure 1, **payback** period = **7.5 years**

If-do-it-yourselfer: cost **(at 1.2¢/sq. ft./R)**
= 32 x $.012 x 1200 = **$460**

— I/S = $460/$93 = **4.94**

— From Figure 1, the **payback** is now **4.7 years**

Actually for a cost of 1.2¢/sq. ft./R the optimum level is as high as 34 x 1.49 or = **R50**

Example 2. I have an electrically heated home in Vancouver. Recently a window manufacturer offered to add storm windows to my 250 sq. ft. of single glazing for $2000. I would use my own money which is in a savings account returning 8.5%. However, I pay tax on that of 47%. Is is really worth it?

— **Effective interest rate:** (1-0.47 x 8.5) = **4.5%**

— **Fuel escalation above interest:** (12-4.5) = **7.5%** (assuming 12% escalation)

— For 25 years lifetime, from Figure 1: **the present worth factor** = **66**

— From Table 4, **savings/sq. ft. for adding storm window** = **0.25¢**

— From Table 3, **the correction factor** = **2.5** (Vancouver-electric)

— **Total Saving/Year:** 0.25 x 2.5 x 250 = **$156.25**

— **Total present worth of savings:** 156.25 x 66 = **$10,312.50**

As compared to today's cost of $2000, it is definitely economical.

Looking at the above differently, **the $2000 in a bank would return 2000 x 0.085 x (1-0.47)** = **$90.1/year (after tax)**
as compared to tax free energy savings = **$156.25**

Moreover, the **saving would escalate at 12% annually, for example:**

— **After 5 years the annual savings would amount** to $156.25 x $(1.12)^5$ or = **$275.36/year**

— If the interest is not taxable: **the present worth factor** = **38**

The **present worth of the savings is:**
38 x $156.25 = **$5,937**

Still a good proposition!

Example 3. For a new oil heated home to be built in Prince George, double 2x4 studs are considered for the walls, to increase the insulation level. The added cost of lumber and labour is about $0.25/sq. ft. Will the savings exceed the increase in mortgage (at 10¼%)?

Two batts of R12 can now be placed between the studs.

The cost of the second R12 should include the additional cost of lumber.

— **Cost/R/sq. ft.:** 1.5 + 25/12 = **3.3¢/sq. ft./R**

— From Figure 2, **the optimum level of insulation,** for the reference case — at 3.3¢/sq. ft./R) = **R20**

— **From Table 1 the correction factor** = **2.03** (Central Interior-oil)

— **the corrected R** is then 2.03 x 20 or about = **R40**

So R24 is more than justified.

— **The overall R value for R24 in the walls** (calculated without allowance for stud effects) = **about R25.7**

— From Figure 3, the **savings/1000 sq. ft.,** for increased insulation from nominal R12 to overall R25.7 (for reference case) is about = **$15/year**

— From Table 3, **the correction factor** = **4.13** (Central Interior-oil)

— **TOTAL SAVINGS** is then 4.13 x 15 = **$62/1000 sq. ft.**

— **Increase in initial cost:** 1000 sq. ft. x 3.3¢ x 12R = **$396/1000 sq. ft.**

— **The increase in mortgage** (for $396 @ 10.25% is about = **$43.30/yr./1000 sq. ft.**

Savings will more than pay for increased mortgage.

Again, the mortgage payment will remain constant at $43.30 for the life of the mortgage. Meanwhile the savings will escalate. **After 10 years, at the assumed escalation rate, the annual savings will amount to $193.**

Example 4. Discuss the economics of retrofitting double glazed windows in Prince George for electrically heated homes.

There are two options available, either add a storm window or another doubled glazed unit.

— From Table 4, the **savings** for the reference case are **for added storm** = **$0.09/sq. ft./year**
for added double glazed = **$0.13/sq. ft./year**

— From Table 3 **the savings correction factor K_S** = **4.36** (Prince George-electric)

— The **actual savings** are

for added storm: 4.36 x $0.09 = **$0.39/sq. ft./year**

for added double glazed: 4.36 x $0.13 = **$0.57/sq. ft./year**

— For the typical present worth factor of 31.4, **the maximum economical cost for retrofit is**
for added storm: $0.39 x 31.4 = **$12.30/sq. ft.**
for added double glazed: $0.57 x 31.4 = **$17.80/sq. ft.**

— **From Table 2, the average cost of adding storm** is about = **$8.00/sq. ft.**
and of **adding double glazing** is about = **$10.00/sq. ft.**

So both cases are economically justified.

The **initial cost/saving ratio** (I/S):

for **added storm** $= \frac{8}{0.39}$ = **20.5**

for **added double glazed** $= \frac{10}{0.57}$ = **17.54**

— Resulting in **payback periods** (from Figure 1) of **17.4** and **15 years** respectively.

It is actually more economical to retrofit from existing double glazing to quadruple glazing than to triple glazing in Prince George — electric heat. Oil heat has very similar economics.

REFERENCE

— For more detailed discussion of the topic refer to:

"OPTIMUM LEVELS OF INSULATION", Project #7838
Energy Use Engineering, B.C. Hydro

— For recommended levels refer to Data Sheet H 206.

— For the "How To" refer to Data Sheet H 210.

ADVISORY SERVICES FOR HOME AND INDUSTRY

Helpful information for the trade and Hydro customers is available from the local B.C. Hydro office or the Energy Use Engineering Department.

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energy use engineering department
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energy conservation division
B.C. Hydro

Insulation is one of the most effective ways by which a building owner can conserve energy and reduce heating equipment installation costs, without sacrificing comfort.

B.C. Hydro recommends the insulation levels shown in this data sheet for good economy of operation and energy conservation.

LEVELS OF INSULATION

Recommended Levels

The recommendations involve some minor compromises between the desirable optimum, the limitations of current construction practice and the requirements of the Canadian Electrical Association's energy efficient ℮ program. Where innovative construction techniques permit, it is desirable to exceed the recommended insulation levels for your area.

To determine the recommended insulation levels for your area:

a) check for your location and fuel type in Table 1 to obtain your applicable category number.

b) refer to that category in Table 2 which will indicate the recommended levels of insulation.

Optimum Levels

Where the insulation is at optimum level, the savings in energy cost over the life of the application will equal or exceed the initial cost of installing it, plus interest on this investment.

Several factors affect the optimum level:

— weather pattern (usually expressed in degree days)
— cost of energy
— installed cost of insulation
— life expectancy of the application
— cost of money (interest rate)
— fuel cost escalation rate

Minimum Levels

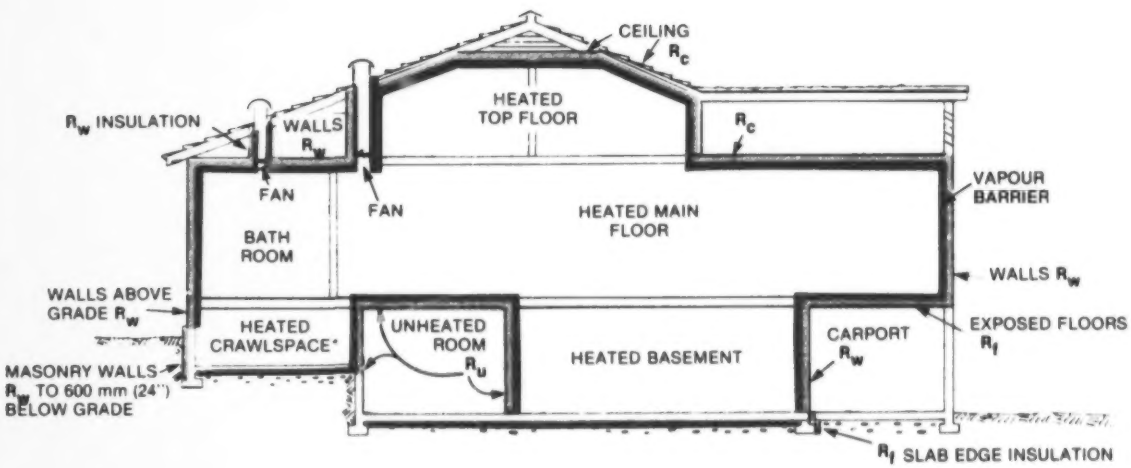
Insulation levels outlined in various building codes and standards are generally minimal good practice because they are intended for mandatory regulation.

These standards, such as the "Measures for Energy Conservation in New Buildings — 1978" or American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) Standard 90-75, often make no differentiation with regard to fuel cost. In British Columbia, the cost of heating identical homes in the same location can vary by a factor of more than two, depending on the fuel used. Consequently, the optimum and the recommendations vary accordingly.

TABLE 1: Category for Insulation Levels

REGION	Lower Mainland	Central Interior	North Coast	Vancouver Island	Southern Interior
CENTRE	Vancouver	Pr. George	Terrace	Victoria	Vernon
SPACE HEATING FUEL / DEGREE DAY °C	3005	5337	4290	2956	3977
Gas	1	2	2	3	1
Electricity	3	4	4	3	3
Oil	3	4	4	3	3

NOTE: The above categories are controlled by degree days and fuel cost. They have been calculated for the centres noted, and for practical purposes they can be applied to the whole of each region. Specific values can be calculated using the method described in Data Sheet H 205.



**If unheated crawlspace, insulate the floor above to R_u*

Figure 1 Recommended Location of Home Insulation

Note: Symbols (R_w, R_c, etc.) are for cross reference to Table 2.

TABLE 2: Recommended Levels of Insulation For Residential and Small Commercial Building Construction[1]

ELEMENT	THERMAL RESISTANCE, RSI[(2)] m^2 C/W			
	Category 1	**Category 2**	**Category 3**	**Category 4**
WALLS (R_W)				
Frame (new)	3.5 (20)	3.5 (20)	3.5 (20)	4.9 (28)
Frame (existing)	If existing wall is uninsulated, fill entire stud space When renovating, try to achieve "new" levels			
Solid wood (over 100mm (4") thick)	3.5 (20)	3.5 (20)	3.5 (20)	4.2 (24)
Solid wood (150mm (6") and thicker)	2.5 (14)	2.5 (14)	2.5 (14)	3.5 (20)
Masonry (over 300mm (12") above grade)	3.5 (20)	3.5 (20)	3.5 (20)	4.9 (28)
Masonry (below grade up to 300mm (12") above grade)	2.1 (12)	2.1 (12)	2.1 (12)	2.6 (15)
CEILINGS & ROOFS (R_C)				
Ceilings, vented above[3]	7.0 (40)	7.0 (40)	7.0 (40)	8.5 (48)
Solid roof deck (new)	7.0 (40)	7.0 (40)	7.0 (40)	7.0 (40)
Ceilings, between floor with radiant ceiling heating	1.2 (7)	1.2 (7)	1.2 (7)	1.2 (7)
Solid roof deck (existing)	Not economical to retrofit unless remodelling			
FLOORS (R_f)				
Over areas exposed to outdoor temperatures	4.9 (28)	5.3 (30) (or maximum of full joist space)	7.0 (40)	7.0 (40)
Slab on grade (edge insulation)				
Heated slab	2.6 (15)	2.6 (15)	2.6 (15)	3.5 (20)
Unheated slab	2.1 (12)	2.1 (12)	2.1 (12)	2.6 (15)
AROUND & OVER UNHEATED ENCLOSED AREAS (R_U)	3.5 (20) (Max. stud or joist space but not less than R20)	3.5 (20)	3.5 (20)	3.5 (20)
WINDOWS & SLIDING GLASS DOORS[4]	Double[5] Glazed	Triple[6] Glazed	Triple[6] Glazed	Quadruple[7] Glazed
DOORS	0.7 (4) or stormed	0.7 (4) or stormed	0.7 (4) + storm	0.7 (4) + storm

1 For large commercial and institutional buildings use life-cycle cost allowing for the tax and situation applicable. Future data sheets in the H 200 will provide suggested methods.

2 Imperial units, usually referred to as "R" value are given in brackets. The resistance values listed are for insulation only.

3 Same levels apply with radiant ceiling elements.

4 All windows should have 12mm (1/2") airspace between glass layers. All metal sash multiple glazed units should have a thermal break unless a storm sash is used.

5 Double glazed windows can be single glazed unit plus storm sash.

6 Triple glazed windows can be double glazed plus storm sash.

7 Quadruple glazed windows can be two double glazed units or a triple plus storm sash.

RECOMMENDATIONS

New Buildings

— For best results, the recommended insulation levels in Table 2 should be installed subject to the limitations listed and to the requirements of national and/or local building codes.

— Roof and ceiling insulation should be carried to the outside of the exterior wall. However, the level may be reduced near the eaves to accommodate the roof slope and ventilation clearance. The minimum insulation value above the exterior wall should be at least RSI 3.5 (R20).

— Insulation applied to the exterior of a masonry wall below grade or to the edges of a floor slab on grade should extend at least 600 mm (24 in) below the adjacent exterior ground level.

— Total window area should not exceed 15% of the floor area and should, where possible, be concentrated on the south-facing wall.

Existing Buildings

— For best results, the floor and ceiling insulation should be increased to at least the recommended levels.

— Walls with existing insulation should be left alone unless renovations make the addition of more insulation practical.

— Walls with no insulation should be insulated by blowing insulation to fill the stud space completely.

— Additional glazing should be added to existing windows, and excessive window area reduced where practical.

INSULATION GUIDE

Data Sheet H 210, "Typical Residential Insulation Practice and Recommendations" outlines further details of good insulation practice, various types of insulation, and their best application. This data sheet is available through your local B.C. Hydro office.

INSTALLATION

The information herein is a guide. B.C. Hydro is not responsible for installations. Installations are the responsibility of the installer and they should meet the current requirements of the owner, manufacturer's instructions and applicable regulations.

ADVISORY SERVICES FOR HOME AND INDUSTRY

Helpful information for the trade and Hydro customers is available from the local B.C. Hydro office or the Energy Use Engineering Department (604) 663-3286.

APPENDIX IV

Penetration Tables

Ceilings, Walls and Windows

PENETRATION FILES

SPACE HEATING : METRO & FRASER VALLEY
NATIONAL LEVELS : R08/R20/B,B

PESSIMISTIC FORECAST

FORECAST YEAR =1985

YEAR		1960	1970	1975	1978	1980	1985	1990	1995	2005
ST LE		7.08	7.78	10.78	12.108	20.120				
SINGLE	DETLD	10	5	3	3	0	75	0	0	0
FAMILY	WALLD	5	0	0	0	0	10	0	0	0
DWELLG	WNDWD	1	1	1	2	0	100	0	0	0
MULTI	DETLD	0	0	0	0	0	0	0	0	0
	WALLD	0	0	0	0	0	0	0	0	0
	WNDWD	0	0	0	0	0	0	0	0	0
ROW	DETLD	5	2	2	2	0	70	0	0	0
HOUSING	WALLD	3	0	0	0	0	10	0	0	0
	WNDWD	1	1	1	1	0	60	0	0	0
OTHER	DETLD	2	1	0	0	0	60	0	0	0
	WALLD	0	0	0	0	0	5	0	0	0
	WNDWD	1	1	1	2	0	50	0	0	0

FORECAST YEAR =1990

YEAR		1960	1970	1975	1978	1980	1985	1990	1995	2005
STYLE		7.08	7.78	10.78	12.108	20.120				
SINGLE	DETLD	10	10	10	10	0	75	80	0	0
FAMILY	WALLD	7	0	0	0	0	10	50	0	0
DWELLG	WNDWD	10	3	3	8	0	100	100	0	0
MULTI	DETLD	0	0	0	0	0	0	0	0	0
	WALLD	0	0	0	0	0	0	0	0	0
	WNDWD	0	0	0	0	0	0	0	0	0
ROW	DETLD	10	5	5	5	0	70	80	0	0
HOUSING	WALLD	5	0	0	0	0	10	55	0	0
	WNDWD	3	2	1	1	0	80	100	0	0
OTHER	DETLD	4	2	1	2	0	60	80	0	0
	WALLD	1	0	0	0	0	5	20	0	0
	WNDWD	1	2	2	3	0	50	80	0	0

FORECAST YEAR :1985

YEAR :		1960	1970	1975	1978	1980	1985	1990	1995	2005
STYLE		7.45	7.78	10.78	12.108	20.120				
SINGLE FAMILY DWELLS	CEILG:	25	20	20	12	3	75	90	100	0
	WALLS:	5	0	0	0	0	10	50	60	0
	WNDWS:	15	10	10	10	0	100	100	100	0
APTS	CEILG:	0	0	0	0	0	0	0	0	0
	WALLS:	0	0	0	0	0	0	0	0	0
	WNDWS:	0	0	0	0	0	0	0	0	0
ROW HOUSING	CEILG:	20	10	10	10	3	70	90	100	0
	WALLS:	7	0	0	0	0	10	55	70	0
	WNDWS:	10	5	5	5	0	80	100	100	0
OTHER	CEILG:	5	3	2	3	2	60	80	90	0
	WALLS:	2	0	0	0	0	5	20	40	0
	WNDWS:	5	5	5	5	0	50	70	100	0

FORECAST YEAR :2005

YEAR :		1960	1970	1975	1978	1980	1985	1990	1995	2005
STYLE		7.08	7.78	10.78	12.108	20.120				
SINGLE FAMILY DWELLS	CEILG:	60	40	40	40	10	80	90	100	100
	WALLS:	10	1	0	0	0	10	50	80	80
	WNDWS:	40	30	30	30	0	100	100	100	100
APTS	CEILG:	0	0	0	0	0	0	0	0	0
	WALLS:	0	0	0	0	0	0	0	0	0
	WNDWS:	0	0	0	0	0	0	0	0	0
ROW HOUSING	CEILG:	25	15	15	15	5	75	90	100	100
	WALLS:	10	0	0	0	0	10	55	70	80
	WNDWS:	17	15	15	15	0	85	100	100	100
OTHER	CEILG:	12	5	5	5	3	60	80	90	100
	WALLS:	5	0	0	0	0	5	20	40	70
	WNDWS:	10	10	10	10	0	50	70	100	100

DATA PREPARED BY J.M.B. & ENTERED BY B.H.P.
DATA REVISED BY B.H.P. & ENTERED BY B.J. 29-JUN-81

Note: Insert is carried responsible to optimistic trend on July 31,1981 by B. June.

PENETRATION FILES

SPACE HEATING : METRO & FRASER VALLEY
OPTIMUM LEVELS : R28/R20/0.2

PROBABLE FORECAST

FORECAST YEAR =1990

YEAR :		1960	1970	1975	1978	1980	1985	1990	1995	2000
STYLE		7.08	7.78	10.78	12.108	20.120				
SINGLE	CEILG:	10	5	5	5	10	80	0	0	0
FAMILY	WALLS:	15	0	0	0	0	55	0	0	0
DWELGS	WNDWS:	7	3	3	3	8	100	0	0	0
APTS	CEILG:	0	0	0	0	0	0	0	0	0
	WALLS:	0	0	0	0	0	1	0	0	0
	WNDWS:	0	0	0	0	0	0	0	0	0
ROW	CEILG:	5	2	2	2	2	75	0	0	0
HOUSING	WALLS:	3	0	0	0	0	45	0	0	0
	WNDWS:	1	1	1	2	2	100	0	0	0
OTHER	CEILG:	5	2	2	2	0	70	0	0	0
	WALLS:	3	0	1	1	0	10	0	0	0
	WNDWS:	1	1	2	2	5	65	0	0	0

FORECAST YEAR =1990

YEAR :		1960	1970	1975	1978	1980	1985	1990	1995	2000
STYLE		7.08	7.78	10.78	12.108	20.120				
SINGLE	CEILG:	20	10	10	10	12	80	100	0	0
FAMILY	WALLS:	25	0	0	0	5	55	80	0	0
DWELGS	WNDWS:	13	6	6	6	13	100	100	0	0
APTS	CEILG:	0	0	0	0	0	0	0	0	0
	WALLS:	0	0	0	0	0	0	0	0	0
	WNDWS:	0	0	0	0	0	0	0	0	0
ROW	CEILG:	15	5	5	5	5	80	100	0	0
HOUSING	WALLS:	10	0	0	0	0	45	75	0	0
	WNDWS:	3	5	5	5	3	100	100	0	0
OTHER	CEILG:	10	3	3	5	3	70	90	0	0
	WALLS:	10	0	0	0	0	10	50	0	0
	WNDWS:	3	3	5	6	10	65	100	0	0

FORECAST YEAR :1985

YEAR :	1960	1970	1975	1978	1980	1985	1990	1995	2005
STYLE :	7.08	7.78	10.78	12	108	20	122		
SINGLE FAMILY DWELLG	DEILG:	40	20	30	20	10	80	100	100	0
	WALLS:	40	0	0	0	2	55	90	100	0
	WNDWS:	20	15	15	17	20	100	100	100	0
APTS	DEILG:	0	0	0	0	0	0	0	0	0
	WALLS:	0	0	0	0	0	0	0	0	0
	WNDWS:	0	0	0	0	0	0	0	0	0
TOWN HOUSING	DEILG:	10	10	10	12	5	80	95	100	0
	WALLS:	30	0	0	0	0	45	75	90	0
	WNDWS:	10	8	2	8	8	100	100	100	0
OTHER	DEILG:	20	10	10	10	5	70	90	100	0
	WALLS:	25	0	0	0	0	10	50	70	0
	WNDWS:	5	7	10	12	15	70	100	100	0

FORECAST YEAR :2005

YEAR :	1960	1970	1975	1978	1980	1985	1990	1995	2005
STYLE :	7.08	7.78	10.78	12	108	20	122		
SINGLE FAMILY DWELLG	DEILG:	40	65	45	45	35	95	100	100	100
	WALLS:	50	0	0	0	2	57	80	100	100
	WNDWS:	40	35	35	40	45	100	100	100	100
APTS	DEILG:	0	0	0	0	0	0	0	0	0
	WALLS:	0	0	0	0	0	0	0	0	0
	WNDWS:	0	0	0	0	0	0	0	0	0
TOWN HOUSING	DEILG:	50	30	30	30	10	80	95	100	100
	WALLS:	40	0	0	0	0	45	75	90	85
	WNDWS:	20	15	15	15	20	100	100	100	100
OTHER	DEILG:	30	15	15	15	10	70	90	100	100
	WALLS:	40	0	0	0	0	10	50	70	85
	WNDWS:	15	20	20	20	25	100	100	100	100

DATA PREPARED BY ZAK & ENTERED BY S.H.P.
DATA REVISED BY S.H.P. & ENTERED BY S.J. 25-JUN-81

Data altered to correct possibility to optimistic trend on July 21,1981
by S. Hale.

PENETRATION FILES

SPACE HEATING : METRO & FRASER VALLEY
OPTIMUM LEVELS : R28/R20/0.3

OPTIMISTIC FORECAST

FORECAST YEAR :1985

YEAR :		1960	1970	1975	1978	1980	1985	1990	1995	2005
STYLE		7.08	7.78	10.78	12.108	20.120				
SINGLE	CEILS:	30	30	20	20	30	100	0	0	0
FAMILY	WALLS:	20	0	0	0	2	75	0	0	0
DWELGS	WNDWS:	10	10	10	10	100	100	0	0	0
APTS	CEILS:	0	0	0	0	0	0	0	0	0
	WALLS:	0	0	0	0	0	0	0	0	0
	WNDWS:	0	0	0	0	0	0	0	0	0
ROW	CEILS:	8	5	2	2	5	50	0	0	0
HOUSING	WALLS:	5	0	0	0	0	70	0	0	0
	WNDWS:	2	2	2	2	100	100	0	0	0
OTHER	CEILS:	5	5	2	2	8	70	0	0	0
	WALLS:	5	0	0	0	0	30	0	0	0
	WNDWS:	2	2	3	5	100	100	0	0	0

FORECAST YEAR :1990

YEAR :		1960	1970	1975	1978	1980	1985	1990	1995	2005
STYLE		7.08	7.78	10.78	12.108	20.120				
SINGLE	CEILS:	50	30	30	20	31	100	100	0	0
FAMILY	WALLS:	35	0	0	0	2	70	50	0	0
DWELGS	WNDWS:	20	20	20	20	100	100	100	0	0
APTS	CEILS:	0	0	0	0	0	0	0	0	0
	WALLS:	0	0	0	0	0	0	0	0	0
	WNDWS:	0	0	0	0	0	0	0	0	0
ROW	CEILS:	20	30	15	15	10	80	100	0	0
HOUSING	WALLS:	10	0	0	0	0	70	50	0	0
	WNDWS:	7	7	7	7	100	100	100	0	0
OTHER	CEILS:	20	10	12	15	10	71	100	0	0
	WALLS:	10	0	0	0	0	70	55	0	0
	WNDWS:	7	7	7	7	100	100	100	0	0

FORECAST YEAR :1985

YEAR		1960	1970	1975	1978	1980	1985	1990	1995	2005
STYLE		7.08	7.78	10.78	10.108	20.120				
SINGLE FAMILY DWELLG	CEILG:	60	60	60	30	35	90	100	100	0
	WALLS:	55	0	0	0	2	70	90	100	0
	WNDWS:	30	30	30	30	100	100	100	100	0
MFG HOUSING	CEILG:	0	0	0	0	0	0	0	0	0
	WALLS:	0	0	0	0	0	0	0	0	0
	WNDWS:	0	0	0	0	0	0	0	0	0
MOB HOUSING	CEILG:	30	30	25	25	20	100	100	100	0
	WALLS:	30	0	0	0	0	70	90	90	0
	WNDWS:	17	17	17	17	100	100	100	100	0
2-4FD	CEILG:	30	30	25	25	15	75	100	100	0
	WALLS:	30	1	0	0	0	30	55	70	0
	WNDWS:	17	17	17	17	100	100	100	100	0

FORECAST YEAR :2005

YEAR		1960	1970	1975	1978	1980	1985	1990	1995	2005
STYLE		7.08	7.78	10.78	10.108	20.120				
SINGLE FAMILY DWELLG	CEILG:	80	80	80	30	30	100	100	100	100
	WALLS:	80	5	2	2	3	70	90	100	100
	WNDWS:	50	50	50	50	100	100	100	100	100
MFG HOUSING	CEILG:	0	0	0	0	0	0	0	0	0
	WALLS:	0	0	0	0	0	0	0	0	0
	WNDWS:	0	0	0	0	0	0	0	0	0
MOB HOUSING	CEILG:	50	50	50	50	25	85	100	100	100
	WALLS:	50	0	0	0	0	70	90	90	100
	WNDWS:	30	30	30	30	100	100	100	100	100
2-4FD	CEILG:	50	50	50	50	20	75	100	100	100
	WALLS:	50	1	1	0	0	30	55	70	100
	WNDWS:	30	30	30	30	100	100	100	100	100

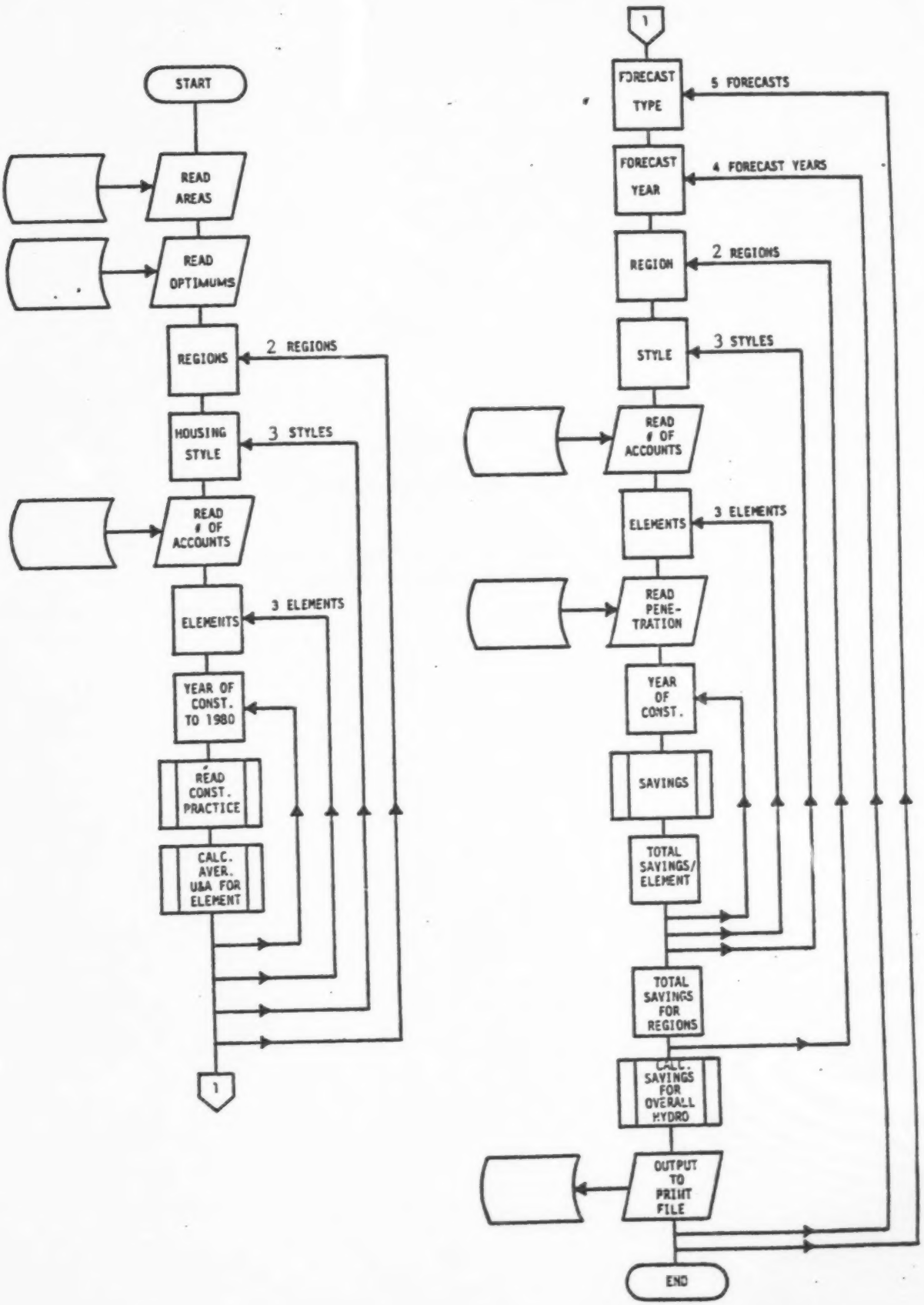
DATA PREPARED & ENTERED BY G.M.P.
DATA REVISED BY S.M.P. & ENTERED BY S.J. 29-JUN-81

Data aligned to current conservative to optimistic trend on July 31,1981.
by to June.

APPENDIX V

Flow Chart of Weatherization Computer Program

FLOW CHART OF WEATHERIZATION COMPUTER PROGRAM



APPENDIX VI

Improved Insulation Levels

Summary of Results Due to Improvements To Ceilings, Walls and Windows

ENERGY SAVINGS FORECASTS FOR GAS ACCOUNTS WITH IMPROVED INSULATION LEVELS

ANNUAL REDUCTION NORMALIZED BY TOTAL ACCOUNTS

BASE YEAR 1980: Average gas space heating consumption per account = 849 Therms/yr.

Region / Forecast		1985 Min.	Pes.	Prob	Opt.	Max.	1990 Min.	Pes.	Prob	Opt.	Max.	1995 Min.	Pes.	Prob	Opt.	Max.	2005 Min.	Pes.	Prob	Opt.	Max.
GAS Therms/yr.																					
Metro	- Old	0	17	33	67	454	0	28	52	99	382	0	40	80	138	340	0	77	123	173	291
	- New	40	43	45	47	49	93	104	109	112	114	136	154	162	164	166	186	215	224	226	228
	- Conv.	-40	-33	-25	-15	86	-43	-31	-13	4	92	-38	-22	4	22	82	-33	-4	18	42	70
	- Total	0	26	53	99	589	50	101	149	214	589	97	173	247	324	589	153	289	365	442	589
Fraser Valley	- Old	0	9	17	43	357	0	18	27	60	285	0	25	41	81	232	0	42	63	87	167
	- New	65	71	76	79	83	101	114	121	124	128	151	175	186	188	192	213	256	267	269	271
	- Conv.	-26	-23	-19	-14	36	-46	-36	-21	-8	63	-37	-25	-6	7	51	-27	-9	5	20	37
	- Total	39	57	74	108	476	56	96	126	176	476	114	175	221	276	476	187	289	335	375	476
All Hydro	- Old	0	14	27	58	417	0	24	42	84	344	0	34	64	114	295	0	61	96	134	235
	- New	49	53	57	59	62	96	108	114	116	120	142	163	172	174	177	198	234	244	245	248
	- Conv.	-35	-29	-23	-15	67	-44	-33	-16	-1	81	-38	-23	0	16	69	-30	-6	12	32	55
	- Total	14	38	61	103	546	52	99	140	199	544	104	174	236	304	542	168	289	351	411	537

ANNUAL REDUCTION NORMALIZED BY ACCOUNT TYPE

BASE YEAR 1980: Average gas space heating consumption per account = 849 Therms/yr.

Region / Forecast		1985 Min.	Pes.	Prob	Opt.	Max.	1990 Min.	Pes.	Prob	Opt.	Max.	1995 Min.	Pes.	Prob	Opt.	Max.	2005 Min.	Pes.	Prob	Opt.	Max.
GAS Therms/yr.																					
Metro	- Old	0	21	43	88	589	0	42	81	152	589	0	70	139	238	589	0	156	249	351	589
	- New	462	496	527	547	566	472	527	555	565	578	475	540	568	573	582	477	553	576	580	585
	- Conv.	-278	-233	-175	-107	602	-282	-201	-84	24	602	-282	-161	31	163	602	-282	-32	156	365	602
	- Total	0	26	53	99	589	50	101	149	214	589	97	173	247	324	589	153	289	365	442	589
Fraser Valley	- Old	0	12	23	58	476	0	30	44	101	476	0	51	84	166	476	0	119	180	247	476
	- New	363	394	422	441	461	362	407	432	444	460	367	426	451	456	467	370	444	463	466	471
	- Conv.	-372	-323	-265	-197	512	-372	-291	-174	-65	512	-372	-251	-59	73	512	-372	-122	68	275	512
	- Total	39	57	74	108	476	56	96	126	176	476	114	175	221	276	476	187	289	335	375	476
All Hydro	- Old	0	18	35	76	546	0	38	67	133	546	0	63	118	211	546	0	142	223	312	546
	- New	406	439	468	488	507	419	470	496	507	521	420	482	509	514	524	418	492	513	517	522
	- Conv.	-303	-254	-196	-128	581	-313	-232	-115	-6	572	-313	-192	1	132	572	-313	-63	127	334	572
	- Total	14	38	61	103	546	52	99	140	199	544	104	174	236	304	542	168	289	351	411	537